Towards a Framework for Enterprise Information System Evolution Steering

Wanda Opprecht, Jolita Ralyté, and Michel Léonard

University of Geneva, Institute of Services Science
Battelle bâtiment A, 7 route de Drize, 1227 Carouge, Switzerland
{Wanda.Opprecht,Jolita.Ralyte,Michel.Leonard}@unige.ch

Abstract. Evolution is characteristic to every Information System (IS) because of continuing changes in its environment. It is also a necessary condition for guaranteeing IS fitness to the organizational needs and requirements. Nonetheless, each IS evolution presents several risks towards its sustainability and further changes, and steering IS evolution is indispensable for any organization. In this work we propose a framework that aims to guide the actors responsible for IS evolution steering. The framework allows to reduce the uncertainty, which is inherent in the IS evolution, by providing the information necessary to realise IS evolution activities and to simulate their impact. It is composed of several conceptual models representing different IS dimensions (information, activities, regulation). In this paper we detail the IS Steering Metamodel (IS-SM), which is the main element of our framework.

Keywords: Information System Evolution Steering, Steering Metamodel, Evolution Model, Evolution Steering Method.

1 Introduction

Information Systems (IS) evolution steering is today one of the key concerns of any organisation[1]. Indeed, evolution is inherent to every IS and evolving is its permanent condition. This is due to its ever-changing environment where contingency may arise from various dimensions such as: business activity (e.g. establishment of new business processes, re-organisation of business units, companies mergers or acquisitions), technology (e.g. introduction of new hard or soft technology), or regulation (e.g. law abrogation or modification, adoption of new industrial standards). In order to ensure IS sustainability (and hence, the information sustainability), its evolution must be understood and supported, i.e. steered.

The main challenge of the IS evolution steering is to cope with the uncertainty which is inherent to any IS change, while taking into consideration its complexity due to the entanglement of its multiple dimensions: regulation (laws and rules governing organisation activities), information (structure and provisioning), activity (business processes and activities), as well as the underpinning technology.

[1] In the following, we use the term 'organisation' to refer to any commercial enterprise, public governmental or non-governmental institution, or an unprofitable association.

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Information systems evolution is necessary but also presents several risks towards their sustainability and further changes. In particular, we can mention two important risks: the failure of IS to appropriately support business activities, and the failure to comply with the enterprise regulatory framework.

Usually, there are more than one IS to be taken into account in the same organisation. Either wholly (or partly) dependent or independent from each other, they support activities of the organisation at different organisational levels (i.e. strategic, tactic, operational). Some of them have been developed and evolve in silos and therefore testify to the consequences of the organisational restructuring (e.g. a merger of two businesses or a fusion of two departments), the evolution of the organisation activities (the development of a portfolio of B2B services for example), or the involvement of the organisation into new partnerships. This situation engenders important issues regarding IS interoperability at the information, technical and organisational levels, and it is particularly manifest when the organisation aims to adopt a service-oriented paradigm [13]. Therefore, in our research we assume that in every organisation several IS are potentially at stake during IS evolution steering.

The ultimate responsibility of the IS steering officer is to ensure IS sustainability at each step of its evolution. In order to support her in this challenging task, we focus on providing a framework that allows to reduce the uncertainty inherent to the IS evolution by exploiting different dimensions of the information available in the IS and by evaluating the impact of any planed IS change before its realisation. Our research assumptions acknowledge the following:

- the domain information is key element for the actors in charge of IS steering;
- the use of conceptual models is the sole and most reliable way to know the IS;
- the best IS steering system is the one based on its model.

We share the point of view of Olivé [17] who conveys the message that conceptual models (in [17] 'schemas') should be the centre of IS developments. In line with this statement, we argue that conceptual models should be the centre of IS evolution steering, too. IS and its evolutions are complex artefacts that can be expressed in a meaningful way with the help of conceptual models. This is particularly relevant for understanding the intertwinement of various IS dimensions [14] which cannot be undertaken otherwise.

The paper is organised as follows: in section 2 we provide the overview of our framework while section 3 is dedicated to the main metamodel of IS evolution steering. In section 4 we position our contribution with regards to the related works, and section 5 concludes the paper.

2 Overview of the Framework

We build our work on the assumptions that i) steering IS evolution requires understanding the underpinning IS domain, ii) the impact of IS evolution is difficult to predict and the simulation could help to take evolution decisions, and iii) the guidance for IS evolution steering is almost non-existent, and therefore needs to be developed. In particular, we propose a framework for IS evolution steering based on several models as shown in Fig. 1. We introduce each of them below.

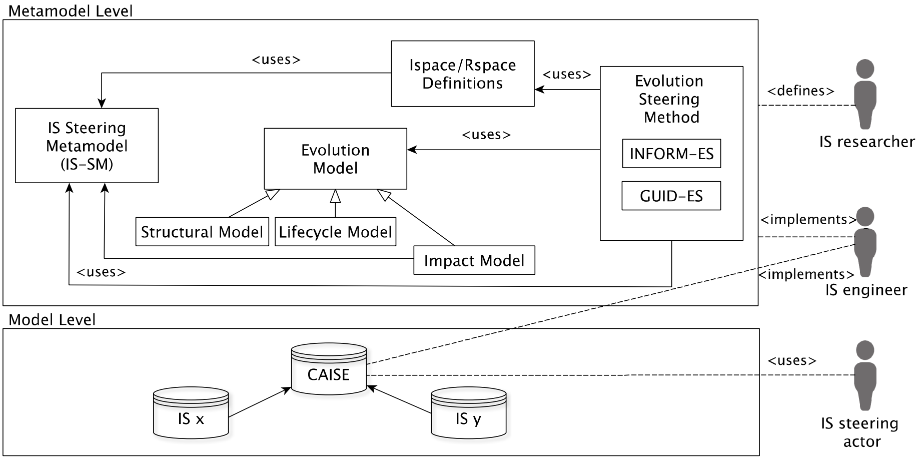

Fig. 1. Overview of the framework for IS evolution steering

2.1 IS Steering Metamodel (IS-SM)

The main element of our framework is the metamodel for IS evolution steering (IS-SM) which homogeneously integrates the activity, regulation and information dimensions (the technology dimension is out of scope of this paper) and seeks to treat their diverse elements in a sufficiently homogenous manner to be taken as a whole. IS-SM represents an information kernel, generic to any organisation, and supporting the evolution steering of several IS in the organisation. On the one hand, IS-SM allows to define the models of the evolution, and, on the other hand, it helps to simulate the evolution and to analyse its effect. IS-SM is further detailed and illustrated in the next section.

2.2 Evolution Models

The purpose of the evolution modelling is manifold. First and foremost, it helps to understand the IS evolution – the concepts at stake and their relationships that represent fundamental elements for IS steering. Secondly, it serves to build a complex artefact with multiple views to facilitate a collaborative work. Third, it supports the decision-making related to the project of evolution. Finally, with a set of models based on information, the evolution realisation is facilitated in each IS dimension with information as a ‘common language’.

In order to understand IS evolution and to identify its potential impacts on the organisation, we develop three models, namely *structural*, *lifecycle* and *impact*.

The structural model defines the schema of an evolution. Indeed, an evolution is composed of several parts; each one is itself an evolution too. Therefore, the structural model allows to capture the complexity of an evolution, to identify the evolution chains, to provide evolution scenarios, and to delimit responsibilities. It is based on the concept of atomic primitive (i.e.: *create()*, *update()*, *activate()* and *inactivate()*).

The lifecycle model allows to represent different possible states of an evolution (e.g.: ready, triggered, succeeded, failed) together with the conditions (transactions) allowing the evolution to pass from one state to another. In case of a failure, it allows to identify its cause (at the primitive level) and to support the choice of the structural model (with an inter-component coordination).

The impact model represents the IS elements that are at stake in an evolution at hand, i.e. directly or indirectly impacted by the evolution. With this model, the evolution can be simulated and potential informational conflicts can be detected.

The three models can be applied for any type of planned IS evolution, regardless the evolution granularity (the whole IS, a particular service, an information element or a mixed granularity), the IS context (with or without a service level, with one or several IS), the trigger (organisation, information or regulation) and the span of the consequences (local to a particular services, local to a particular IS, or global). Moreover, these models do not rely on a determined steering metamodel. They can be easily adapted to any other steering metamodel than IS-SM.

2.3 Ispace/Rspace

The impact analysis of an evolution is often too challenging to conduct due to the number of entities and possible points of view it implies. The use of IS-SM allows concentrating the attention on the main evolution stakes – to identify all the entities that are directly or indirectly concerned by the evolution. Thus, it contributes to reduce the risks [23] of information overload, which could lead the steering actors to paralysis, to misleading estimations, or to inappropriate decisions. However, too much and too complex information is still at stake.

In order to reduce the complexity of the information space concerned by a particular evolution and, therefore, to facilitate the IS evolution impact analysis, we define a model named Ispace/Rspace. In particular, the role of Ispace/Rspace is to reflect the notion of responsibility in IS evolution steering.

Our assumption is that responsibility is a key concept for the impact analysis of an evolution. Inspired by [9] and [12], we define responsibility as a set of information entities that represents the accountabilities and the capabilities of an actor (or group of actors) to perform a task.

With Ispace/Rspace, we create sub-sets of information that allow informing the steering actors about the changes caused by an evolution affecting the responsibility. Two perspectives are taken into account: the information perspective, named Ispace, represents the responsibility over information elements, and the regulatory perspective, named Rspace, represents the responsibility over regulatory elements.

Ispace and Rspace are defined on the basis of the IS-SM and allow to simulate IS evolutions and to identify potential risks.

2.4 Evolution Steering Method

The last, but not least, component of the meta-method level of our framework is the *Evolution Steering Method* that aims to guide the actors in charge of IS evolution steering in order to support their activity.

Evolving implies for an IS to move from a known to an expected, but at the same time unknown, situation. Actors steering this evolution are responsible for the decision making under a certain level of uncertainty. This situation is characterised by risks that are either positive or negative deviations from the expectations. Consequently, guidance is a way to help IS steering actors in identifying risks, taking decisions about their handling and finally handling them.

Furthermore, IS evolution may fail due to its complexity caused by its various aforementioned dimensions. Guidance for IS evolution steering is essential for understanding and taking into account the various and interrelated components that constitute the complexity of the evolution situations.

Our Evolution Steering Method includes two interrelated models: the product model named Information Model for Evolution Steering (INFORM-ES) and the process model named Guidance for Evolution Steering (GUID-ES). INFORM-ES is based on the IS-SM, Ispace/Rspace and the evolution models; it includes concepts necessary to serve the purposes of GUID-ES. GUID-ES is an intention-driven process model providing semi-formal guidelines for IS evolution steering. In particular, it is composed of four ordered intentions, namely *Build evolution*, *Assess risks*, *Do the transition* and *Operate the evolution* and provides guidelines to reach these intentions. The set of guidelines altogether form a situational process model that can be adapted to each specific IS evolution situation and could be easily supported by a tool as introduced below.

2.5 CAISE

The formalisation of our framework allows to build a Computer-Aided Information Steering Environment (CAISE) – a powerful tool allowing to guide the steering actors in the IS evolution process. It would, for example, provide a step-by-step navigation from large-grainer to finer guidelines as well as an information space for evolution impact simulation.

To conclude this overview, we claim that our framework provides a concrete guidance for steering IS evolution, which is applicable to any type of organisation. It unveils the strong potentialities of IS models exploitation where information represents a means to address strategic concerns of IS evolution and to provide related operational support for decision-making.

2.6 Running Example: Split of a Faculty

We now introduce an example that will be used to illustrate different parts of our framework in the following section. It is inspired from a real, but rather unusual, situation – a University decides to split one of its faculties (let’s say the Faculty of

Economics and Social Sciences (ESS)) into two new ones (Faculty of Economics and Business (EB) and Faculty of Social Sciences (SS)). The Faculty of ESS was founded a century ago and offers more than twenty programs of initial education (Bachelors, Masters and PhDs) and the same amount of continuing education. It is clear that such an important evolution of the University organisation has impact on its activities, people (students, professors, administrative staff) and information systems, and cannot be done without a thorough consideration and steering. In our work, we claim that most of the information regarding organisation's activities, roles and rules lies in its information systems. The Faculty of ESS exploits several information systems and in particular: *StudentsIS* for the enrolment of students in different faculty programs, *ProgramsIS* for the design and updates of the education programs, *CoursesIS* for the registration of students to different courses and exams and managing their evaluations, and *RoomsIS* for booking rooms for courses.

The split of the faculty is a complex and planed organisational evolution that leads to inevitable changes in the underpinning IS. University IS cannot be put on hold or easily replaced. Students must be able to continue to register to courses, professors still have obligation to give courses and evaluate students and the administrative staff are responsible for booking rooms for courses in each of the two new Faculties.

3 IS Steering Metamodel

The *IS Steering Metamodel (IS-SM)* embodies the foundation of our framework for IS evolution steering. It is composed of three inter-related models: *Activity*, *Regulatory* and *Information*. The IS-SM components and their relationships are shown in Fig 2.

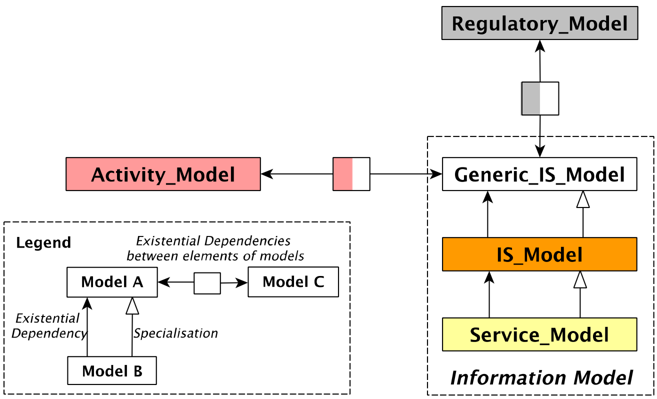

Fig. 2. The structure of the IS Steering Metamodel (IS-SM)

3.1 The Activity Model

The *Activity Model* intents to represent the interpretation of a perception [21] on the organisation of business activities. These activities can be carried out at the operational level (e.g. creating a new Master program), tactical level (e.g. planning the split of the faculty) or strategic level (e.g. developing a vision for the new faculties). They are specific to a given organisation (e.g. a company, a non-profit association or a governmental agency, a university in our case).

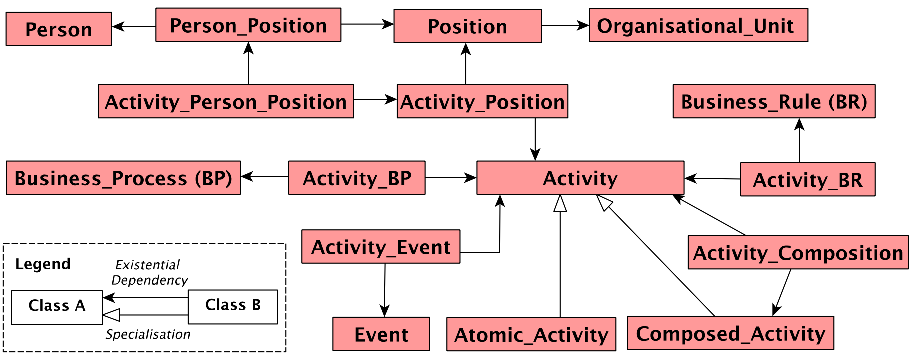

Fig. 3. Metamodel of Activity Model

As shown in Fig. 3, the activity model defines how organisational *activities*, that can be atomic or composed, are related to *business processes* and *positions* held by *persons* in different *organizational units*. A person holding a position may be responsible for a set of activities defined for the position. Activities are governed by *business rules* and may trigger or be triggered by *events*.

For example, the activity model allows to structure the following information (see Fig. 4): John Doe is a person who holds the position of professor in the Faculty ESS. Among the activities of this position, he is in charge to lead a Master program on Business Administration.

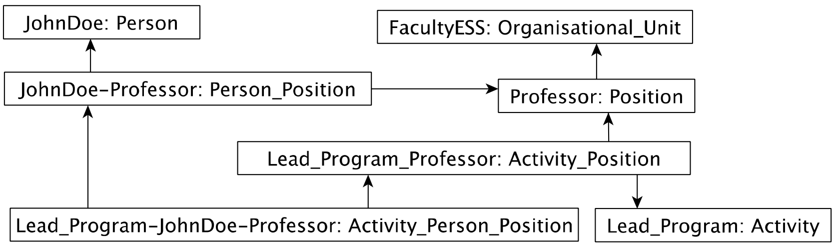

Fig. 4. An excerpt of the activity model describing University activities, roles and responsibilities

3.2 The Regulatory Model

The *Regulatory Model* allows to specify the necessary, unquestionable and invariant concepts and their relationships identified in laws, policies and other regulations (e.g. SOX[2], ISO 9001[3], a particular regulation of the organisation) that govern organisation's activities and to which the organisation must/decides to comply.

The metamodel depicted in Fig. 5 defines the regulatory model. A *regulatory source* is a legal base or industrial standard which is used as a common base for the IS development. A *fragment* of a regulatory source may be a law article, or a paragraph of a standard. A *regulatory element* may be a *concept*, a *regulatory role* or a *regulatory rule*. It originates from one or several regulatory fragments. A regulatory concept is an abstract construct defined in a regulatory source (e.g. scientific committee). A regulatory role represents a set of necessary responsibilities, authorities and capabilities, expressed in laws, to perform the execution of activities or to supervise the execution of activities performed by other roles. A regulatory rule represents a rule defined in a regulatory source governing organisation's activities.

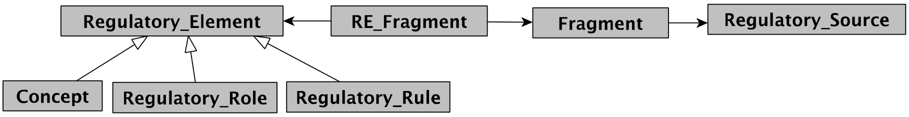

Fig. 5. Metamodel of Regulatory Model

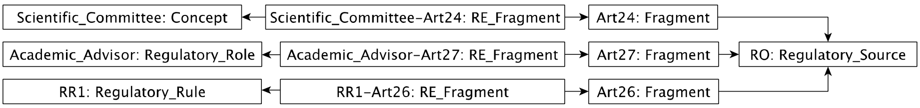

Fig. 6. An excerpt of the University regulatory model

The example in Fig. 6 shows that the Faculty ESS is ruled by the *Rule of Organisation*[4], where the concept *Scientific_Committee* (art. 24), the regulatory role of *Academic_Advisor* (art. 27) and the regulatory rule *RR1* regarding the creation of a new program (art. 26) are extracted.

3.3 The Information Model

The *Information Model* is composed of three models: the *Generic IS model*, *IS model* and *Service model* (see Fig. 2).

The purpose of the *Generic IS metamodel* is to represent an integrated view of the IS level which can consist of several IS. It allows inter-relating the Information model with the Activity and Regulatory models. Fig. 7 depicts a small part of this metamodel; it defines the generic concepts such as *class*, *role* and *treatment*. A role is

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[2] Sarbanes-Oxley Act, `http://www.govtrack.us/congress/bills/107/hr3763/text`

[3] ISO 9001, `http://www.iso.org/iso/home/standards/management-standards/iso_9000.htm`

[4] Règlement d'organisation `http://www.unige.ch/ses/telecharger/faculte/ro2012.pdf`

a responsibility pattern that may be assumed by several actors. It is associated to a class and/or to a treatment in order to specify the authorisations that the role has over the class objects or treatments.

For example, the generic role *Program_Director* has responsibilities over the class *Program* and over the treatment *Offering_Program*. It can be implemented in one or several IS of the Faculty ESS (see Fig. 8).

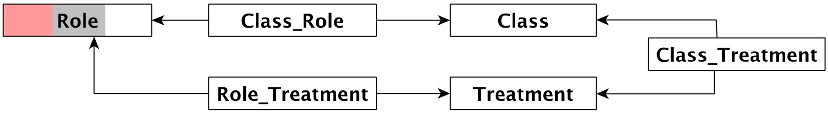

Fig. 7. An excerpt of the metamodel of Generic IS Model

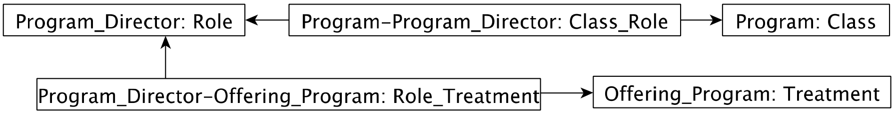

Fig. 8. An example of instantiation of Generic IS Model

The *IS level metamodel* has been built upon the Generic level metamodel in order to add to it the information elements relating to the IS level. From now on, an IS defines itself as a restriction of the generic level previously described. Indeed, two or more IS may support the activities of an organization. For example, as mentioned above, the activities of the Faculty ESS are enabled trough several IS such as *StudentsIS*, *ProgramsIS*, *CoursesIS* and *RoomsIS*. They may share some of their information elements (classes, methods, treatments, etc.), i.e. related to the same generic element. Fig. 9 shows a small excerpt of the IS level metamodel named IS-Model, and its links with the Generic IS Model.

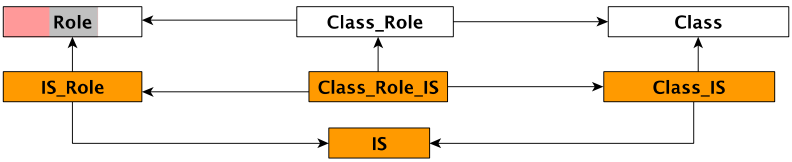

Fig. 9. An excerpt of the metamodel of IS-Model

To illustrate the instantiation of the IS-Model we can mention that the generic role *Program_Director* exists in the IS *ProgramsIS*, where it is responsible for the class *Program* (see Fig. 10).

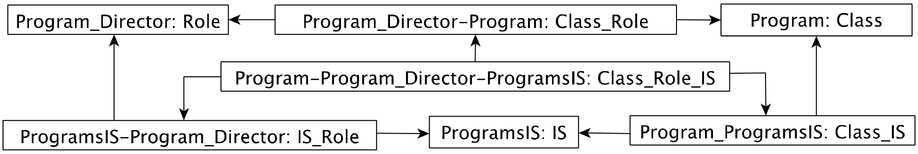

Fig. 10. An example of instantiation of IS model representing an IS role

Finally, the *Service level metamodel,* named *Service-Model,* defines the elements of an information service[5]. In our approach, a service shares the same metamodel as an IS. A service is a specialised IS which is based on one or several IS. Fig. 11 shows only very small part of the service level metamodel that allows to identify the information systems used by a service.

Fig. 11. An excerpt of the metamodel of Service-Model

For example, Fig. 12 shows the service *Master_Admission* that has been built on two IS, *StudentsIS* and *ProgramsIS*, in order to support the process of the admission to the master programs more efficiently. It allows for the applicants to send their application files directly to the administrative staff, the program director and the scientific committee, to evaluate the application.

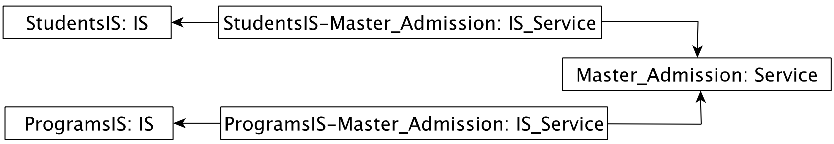

Fig. 12. An excerpt of service model representing a service built on two IS

Altogether the models constituting the IS-SM aim to reduce the uncertainty pertaining to the situation of IS evolution. In particular, they help to identify and understand the elements at stake when steering a particular IS evolution (inform the evolution), and to specify, via simulation, direct and indirect impacts of this evolution (analyse the evolution simulation).

Let us take as example the Evolution *E1* illustrated in Fig. 13, which, because of the split of the Faculty ESS, consists in the creation of a new organisational unit (*FacultyEB*). This creation implies other actions like the creation of the position of professor in this new Faculty and the related activity of leading a program. John Doe who used to be professor in *FacultyESS* is now affected to *FacultyEB*. In this new position, he takes the lead of a program and receives the new role of

[5] Hereafter, the term service is used for ‘information service’.

DesignerEBProgram, which enables him to add and remove courses to/from this program in the *ProgramIS*.

In the simulation environment, this evolution is processed on the IS-SM data, which have been extracted from the actual University IS. The resulting IS-SM data are then analysed and related risks may be identified[6].

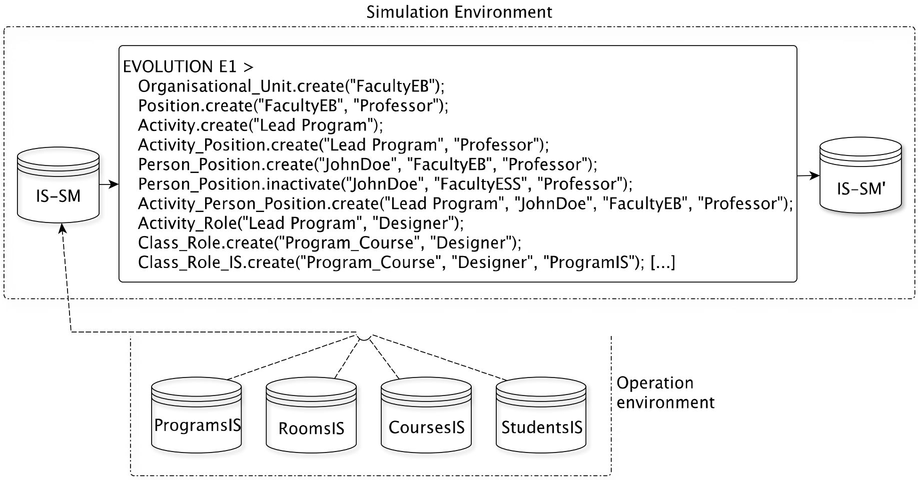

Fig. 13. Example of simulation of the Evolution E1

4 Related Works

The literature review reveals that there is no consensus on the definition, goals, models and methods of IS evolution steering. This domain is at the crossroads of several IS research areas such as: Enterprise Architecture (EA), Enterprise Modelling, Business/IT alignment, IS Governance and Risk Management. Below we discuss a few related approaches, which contribute to the understanding of the IS evolution steering stakes.

4.1 Enterprise Architecture Models

Many Enterprise Architecture (EA) frameworks have been proposed since 1987 when Zachman created the 'Zachman Framework' [28]. Some of them originate from industry (e.g. TOGAF[7] [19]), other from research projects (e.g. GERAM[8] [5], CIMOSA[9] [2], PERA[10] [27], GRAI-GIM [8], EKD-CMM[11] [4]) or even from

[6] The method for analysing the simulation and identifying the evolution risks are not presented here due to the space limit.

[7] TOGAF: The Open Group Architecture Framework.

[8] GERAM: Generalised Enterprise Reference Architecture and Methodology.

[9] CIMOSA: Computer Integrated Manufacturing Open System Architecture.

governments (e.g. the Finnish GEA[12] [25], the US FEA[13] [18], the US Department of Defense DodAF[14] [7]).

However, despite a large number of approaches, there is no common agreement on the definition of EA, because it can be approached from a number of viewpoints [16] such as products (especially structural models), services (such as architectural guidance), processes (e.g. creating and updating EA products), outcomes (e.g. systems or processes implemented according to EA) and benefits (e.g. improvement of business-IT alignment). Most of the frameworks acknowledge the need for multiple views in order to manage complexity, separate concerns and address different life spans of the architecture elements [3]. These approaches often expose best practices and generic principles, but fail to offer a formal steering method. Moreover, they do not exploit information as a 'common language' between different IS dimensions that we do with our IS evolution steering model.

4.2 Business/IT Alignment

Business/IT alignment has been one of the main concerns for both IS practitioners and researchers since two decades, particularly in the domain of IT/IS Governance [15, 26] and in the discipline and practice of EA. It consists in the design, restoration and evolution of the alignment between business activities and the IS enabling them. According to Henderson and Venkatraman [10], business/IT alignment aims to reach a degree of strategic fit and functional integration between enterprise business and IT (their respective strategies and infrastructures and processes). Reich and Benbasat [22] define business/IT alignment as a degree to which the information technology mission, objectives and plans support (and are supported by) the business mission, objectives and plans. Most of the time, the alignment implies two entities and therefore, is bivariate [10]. But, it can also imply several entities and be cross-domain [10] or multivariate. Usually, one of these entities corresponds to the business domain and the other to the IT domain. The systematic review of alignment presented in [24] suggests four directions for the study of the alignment process: the business strategy, business structure, business culture and social directions.

As an answer to the integration of multiple IS dimensions, there is a large amount of works suggesting business/IT alignment. However, none of them, to our knowledge, includes three IS dimensions: information, regulation and activity, neither takes into account multiple IS at once. Furthermore, these approaches often fail to take into account the inherent characteristic of the IS level – the permanent evolution of its entities. Besides, the IS model is not used as a source of the integration of different IS dimensions.

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[10] PERA: Purdue Enterprise Reference Architecture.
[11] EKD-CMM: Enterprise Knowledge Development - Change Management Method.
[12] GEA: Government Enterprise Architecture.
[13] FEA: Federal Enterprise Architecture.
[14] DodAF: Department of Defense Architecture Framework.

4.3 IS Evolution Metamodels

The techniques of evolution in IS and software engineering are mostly based on models [1, 6, 11, 20]. These research works mainly address the problem of structural evolution (e.g. changing a hierarchy, adding a class) [20]. Their intention is to support the change propagation in order to allow the automation of data migration, to evaluate the impact of metamodel changes on models, to support forward-, reverse–, and re-engineering techniques or to record the model history. Some works are language-dependent (for example UML, EMF, MOF), while others are not. However, these models are not designed for IS evolution steering purposes and are not considered as means to support decision making in IS evolution, which is the purpose of our framework for IS evolution steering.

To sum-up this literature review, we claim that, to our best knowledge, there is no another holistic approach supporting IS evolution steering that the one we propose in this paper.

5 Conclusion

Every change in enterprise organisation, business activity, or regulation inevitably entails a chain of evolutions of its information systems and services. Actors, responsible for IS evolution steering, have to take important decisions those impact on the enterprise business and IS can be devastating. To be able to make these decisions, they must have a thorough knowledge of the situation, and we claim that this information can be extracted from enterprise information systems.

In this paper, we present an overview of a framework dedicated to support enterprise IS evolution steering and to help IS steering actors to take critical decisions. The framework aims to address IS sustainability issues by proving clear and complete information allowing to simulate IS evolution and to assess the impact of its changes. Especially, it allows to reduce the uncertainty that the actors responsible for IS steering are facing at each IS change, and to guide them in such a hazardous task.

The framework is composed of several models that represent different and complementary IS evolution perspectives such as: related information structure, evolution lifecycle, impact of the organisation and its IS, and responsibility, and provides guidance to exploit these models. The main part of the framework, the IS steering model (IS-SM) that captures the fundamentals of the approach, is detailed and illustrated in this paper.

Our main future research perspective concerns the integration of the technology dimension into our framework. It starts with the extension of IS-SM with software and hardware infrastructure components. It could lead the steering actors to identify potential security risks caused by an evolution.

Our framework paves the way to the building of a novel Computer Aided Information Steering Environment (CAISE) dedicated to support the activities of IS evolution steering led by information. It unveils the strong potentialities of IS models exploitation for reducing the uncertainty inherent to the evolution steering, and for allowing the actors of multiple IS dimensions to collaborate, which is the most promising approach for the pursuit of a sound and sustainable IS evolution.

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