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Project acronym: BIM4VET

Project title: Standardized Vocational Education and Training for BIM in EU

KA2- Cooperation for Innovation and the exchange of good practices strategic partnerships for vocation education and training

IO3. METHOD FOR BIM MATURITY ASSESSMENT

Dissemination level	Public
Activity	3 – Method of BIM qualification maturity assessment
WP Leader	Cardiff University
Contributor(s)	LIST, CEA
Authors	Alex Bradley, Simon Lamb, Dr. Haijiang Li
Status (F: final, D: draft)	F

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Acronym

BIM   Building Information Modeling

BIM4VET   Standardized Vocation Education & Training for Building Information Modelling

AECOO   Architecture, Engineering, Construction, Ownership & Operation

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1.   Introduction

Building Information Modelling (BIM) has emerged into the mainstream bringing a difference process of collaboration and a new way of working transforming current AECOO (Architecture, Engineering, Construction, Owner and Operator) industry structures and practices, with the aim of improving cost, efficiency & environmental objectives [1]. The subject of BIM has expanded to a central topic moving to become a necessity rather than a tool for competitive advantage. With any new process or technology, the continued Professional development of new skills is key to moving companies forward and maintaining a steady stream of work.

With the need for new skills in BIM, the project Standardized Vocational Education and Training for BIM in the European Union (BIM4VET) addresses the need to standardize the quantification of skills provided by European training offerings, the representation of maturity for individuals, Organizations & Projects and development of a skills matrix for BIM Actor definitions.

The objectives of BIM4VET are to contribute towards the European Area of Skills and Qualification by focusing on the issue of transparency and a comparative base in BIM Qualifications & training. In addition, the definition of individual abilities and objectives which can be intrinsically linked to a standardized representation of Training prerequisites and learning outcomes. It will also be the first steps towards a convergence roadmap for European training curriculums.

Within the BIM4VET framework, the Luxembourg Institute of Science of Science and Technology (LIST) - who is the coordinator of this European project, in collaboration with Cardiff University will develop a European skills matrix for BIM actors and a method for assessing the maturity of skills of individuals and projects using tangible and web-based interfaces. Enabling the quantification of BIM skills and objectives to be assessed individually and collectively for BIM actors working together on a digital Construction Project using BIM Processes.

2. Background & Problem Definition

2.1. Research Context

BIM is defined as the art of information management & collection by CPIC (Construction Project Information Committee); a process that runs through the entire asset lifecycle [2], [3] and a Digital representation of physical & functional elements of an asset used for decision making[4]. Since the early 2000's numerous industry and academic articles, research projects and papers have been conducted to improve the quality of construction information utilizing BIM based technologies and processes to reduce time and cost of construction projects. In addition, the good practice around information management and BIM concepts has been updated to embrace a digital way of working and the exchange of graphical and non-graphical data models.

Much work has been done internationally around BIM, with the UK cited as a figurehead in the development of many BIM standards and processes (McGraw Hill). These standards, BS1192 [5] & PAS1192-2 [6] are being incorporated into the BIM international standard ISO19650. Within PAS1192-2 BIM is defined as the "process of designing, constructing or operating a building or infrastructure asset using electronic object-oriented information".

With the emergence of new technologies and new best practices within an industry it is a necessity to provide new training for emerging professionals at an academic level, and the provision of upskilling and continued professional development for existing professionals. This need has triggered an explosion of new training offerings focused around the BIM concept, both nationally and internationally, providing a wide variety of choices for industry professionals.

While the development of BIM has generated a multitude of training offerings, little work has been done around quantifying the skills and capabilities of an individual and learning outcomes for courses. a Learning Outcome Framework has been developed outlining the knowledge required of a BIM professional, however this falls short of outlining the specific competencies required, despite industry research identifying a gap in BIM related skills. To date little research has been completed around BIM competencies.

Positively, much work has been done by BIM excellence around a framework for BIM competencies, defining them as "a specialized type of Competency representing the ability of an individual or team to generate pre-defined BIM Deliverables" [7].

However, this definition does not consider other non-deliverable based activities such as the need to validate and verify data within deliverables once they are produced. Therefore, there is a need to utilize a broader definition.

ISO 17024 defines competency as: "ability to apply knowledge and skills to achieve intended results". This definition is more suitable to capture competencies, which are not directly associated to the production of deliverables. Otherwise little research has been conducted on this topic.

Some research is available on BIM 'skills' but relate to the higher-level competency topics as opposed to competency items through a study involving LinkedIn endorsements [8]. In addition, a similar schedule of competency topics was also collected through an analysis of job advertisements [9], and includes mainly software proficiency competencies.

Subsequently, there is an opportunity to produce a framework able to quantify the skills and objectives of an individual and by extension projects and organizations using standardized definitions for BIM activities within projects. This quantification can then be used in conjunction

with standardized definitions of Training learning outcomes to better target and identify relevant offerings within the market. In addition, a standardized quantification of skills can be utilized within the contractual domain as evidence that individuals and indeed organizations are competent within the required parameters of a project.

2.2. Problem Definition

To Address the need for standardized vocation training in BIM and the ability to both quantitatively assess maturity and set objectives for agents (defined as Individuals, organizations or projects) undertaking BIM based activities in the AECOO industry, this element of the BIM4VET research delivers a framework and implementation for the assessment of agent maturity for BIM based activities and practices.

The research incorporates the definition of a self-assessment process based on reviewable evidence, and a conceptual model able to quantify agent skills and objectives in relation to a defined set of universal BIM activities. These activity competences provide the comparative link between defined training specifications and aggregated project requirements and skill maturity.

The research has been conducted through systems development cycle defining conceptual models and processes implemented into a demonstrative web-based tool.

2.3. Relation to Other Intellectual Outputs

Within the BIM4VET Framework illustrated by Figure 1 BIM maturity assessment sits as an interaction point and first entry point to the BIM4VET system, allowing users to define their personal skill set and objective set within the central database. This can then be evaluated in conjunction with the Repository of BIM training offerings developed through IO2 [see related deliverable for more details], by the Recommendation engine developed through IO3 [see related deliverable for more details], to produce individually tailored recommendations for courses to achieve the users' objectives (IO4 [see related deliverable for more details]). The maturity assessment is also used in conjunction with the BIM Profiles developed through IO1 [see related deliverable for more details] to provide a both a simpler representation of user maturity and to reduce overall complexity of the maturity assessment. In addition, the BIM4VET Portal (the implementation of the maturity assessment) operates in unison with the collaborative tangible interface developed & tested through IO5 & 6, enabling collaborative planning of course attendance by an AECOO project team, to meet the skill requirements of a given project.
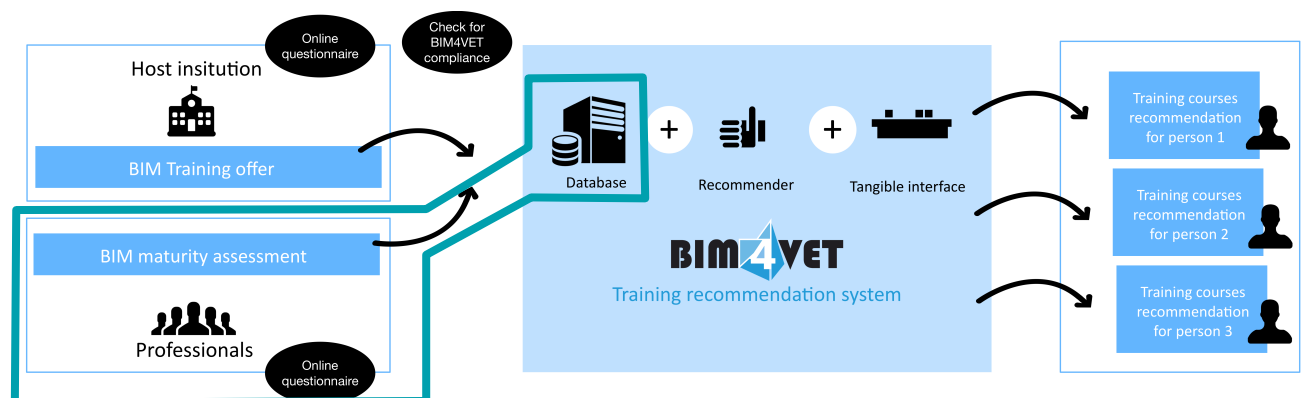

Figure 1 BIM4VET Framework System Architecture

2.4. Research Methodology Flow Chart

The research methodology conforms to the following schema (see Figure 2).
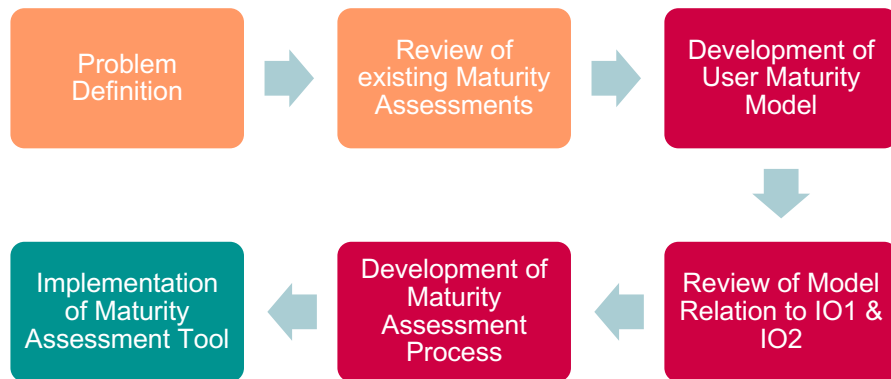

Figure 2 Research Methodology Flow Chart

3.   Framework Development for Maturity Assessment

The Framework for Maturity Assessment is a conceptual model and self-assessment process that provides the quantification of an agent's skills & objectives in relation to BIM activities, competencies and completed training. The full conceptual model can be viewed in Appendix I and is discussed in the following sections.

3.1. Definition of Competence

A competence is described as "the ability to do something successfully or efficiently". In this case that something consists of a specific BIM task or responsibility (see Table 3), or a more atomic competency (See Table 4). To be able to quantify this competence it becomes apparent to define or apply some measurement scale to describe the level of skill acquisition by the subject. One such theory is known as the Dreyfus model of skill acquisition proposed by Stuart and Hubert Dreyfus from the University of California, Berkeley [10]. The model proposes that a learner or developing professional passes through five distinct stages of competence, these stages, as summarised by Michael Eraut [11] are shown in Table 1.

Table 1 The 5 stages of skill acquisition (Michael Eraut, 1994)

Stage	Definition
0 – None	No taught or earned knowledge relevant to the specified task
1 - Novice	Rigid adherence to taught rules or plans with no exercise of "discretionary judgement"
2 - Advanced Beginner	Limited "situational perception" and all aspects of work treated separately with equal importance
3 - Competent	The ability to "cope with crowdedness" (multiple activities, accumulation of information), some perception of actions in relation to goals, adopts deliberate planning of task execution and formulates routines to recursively execute task effectively
4 - Proficient	Has a holistic view of a situation, prioritizes importance of aspects, "perceives deviations from the normal pattern", employs maxims (ground rules or subjective principles of action) for guidance, with means that can adapt to the situation at hand.
5 - Expert	Ability transcends reliance on rules, guidelines, and maxims, has an "intuitive grasp of situations based on deep, tacit understanding". Has "vision of what is possible" and uses "analytical approaches" in new situations or in case of problems

In the novice stage, a person follows rules as given, with no sense of responsibilities beyond following the rule exactly, due the fact that the individual does not have enough knowledge to employ any discretionary or informed judgement. Competence develops when an individual can form organizing principles to quickly access the rules or guidance relevant to the specific task, hence competence characterizes the ability for active decision making in choosing a course of action. Proficiency takes this active decision making and operational ability further utilizing intuition and the development of their own rules and constraints based on each individual

situation. Lastly, Experts can complete on tasks and have a situational awareness derived from a deep, tacit understanding, and is able to not only guide the situation but forecast possible outcomes. In summary this illustrates a progression from rigid adherence to rules and instructions to an intuitive mode of interpretation and reasoning based on tacit knowledge.

Within this research context this project these stages are represented as a 0 to 5 scale and form the definition of the 'Level of Competence'. This framework defines 2 types of competences within its model (depicted by Figure 3) that can define a skill competence level in relation to a BIM activity/responsibility or an atomic competency. It can also be noted that through the work conducted with regards to the definition of BIM roles, responsibilities & competencies [#], each activity has a related collection of BIM competencies that are expressed as a requirement to conduct that activity. Thus a competence in an activity has a set of inherent competences in the related competencies, this relationship will be described and discussed further in sections 3.3 and 3.5.
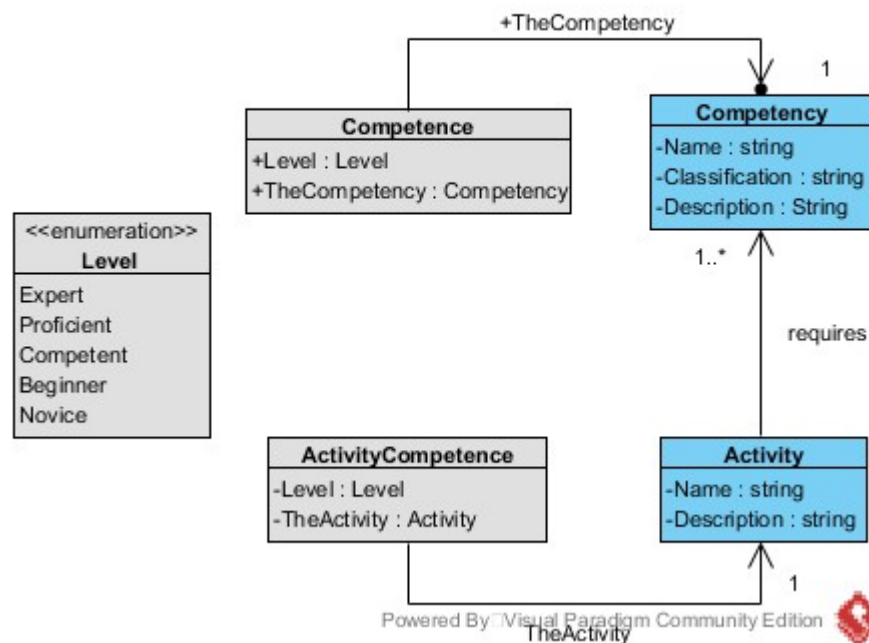
Figure 3 Class Diagram depicting Competence

3.2. BIM4VET Roles Definitions & Course Repository

The BIM4VET framework for maturity assessment utilises the developed BIM profiles, responsibilities & competencies [see IO1 & IO2] as a tool to simplify the definition of user skills and objectives. The conceptual model for the BIM profile (Figure 4) aggregates a set of activity competences for expressing the responsibilities of the specific BIM role profile. In relation to the maturity assessment, an axiom stating a user has the skill of BIM Author (a Profile instance), allows a set of activity competences to be inferred based on the defined responsibilities of the profile. In addition, the same principle can be used to infer the relevant set of competences in BIM competencies from the requirement relationships defined between Activities and competencies. For the current set of BIM profiles, responsibilities and competencies developed as part of this research, see Appendix III, and are discussed further in report IO1, and IO2 [see related deliverables for more details].

The BIM4VET Framework also defines a model that represents BIM training offerings (Figure 5). The conceptual model represents the prerequisites and learning outcomes of training as competence definitions, providing another method to simplify the definition of user skills and

objectives. The maturity assessment utilises axioms of the type 'User A' 'has completed course' 'Training A' to both record the achievements and developments of a user and infer the learner's activity competences from the defined learning outcomes of the training offering.

The use of BIM profiles and training definitions as part of the self-assessment process reduces the level of interpretation required by the learner in relation to the maturity levels by transferring the task to the consensus research of the BIM profiles, and the expertise of the training providers.
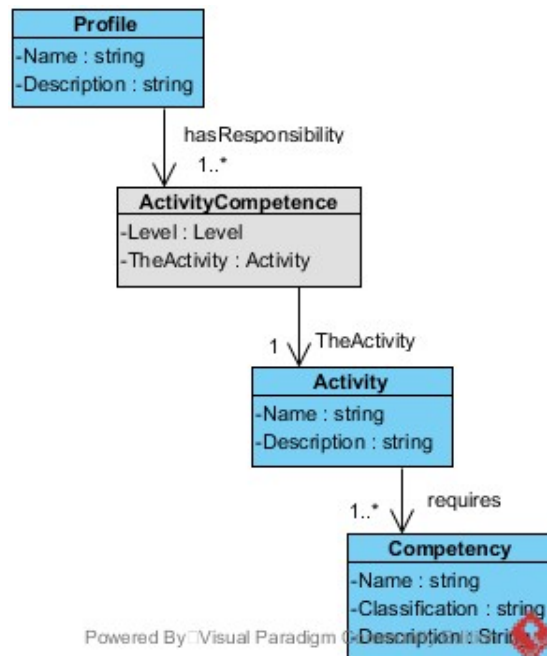

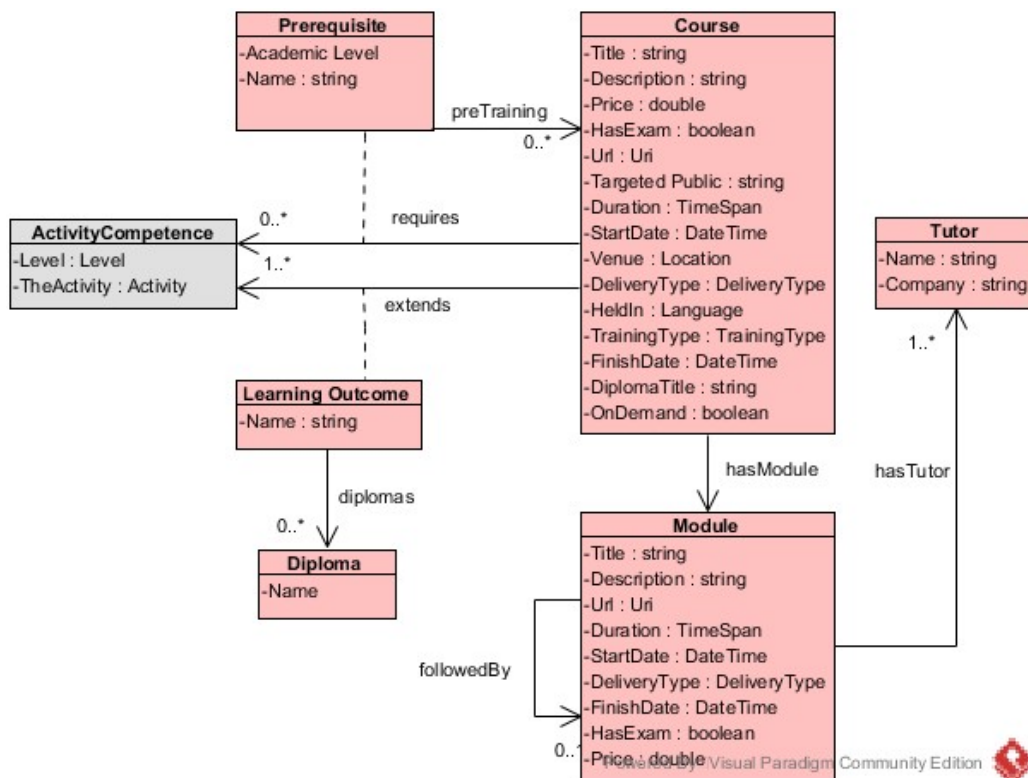*Figure 4 UML Conceptual Model for BIM profiles and related BIM activities*

Figure 5 UML conceptual model for BIM training

3.3. Definition of Agent Maturity

The Definition of Maturity is stated as "The advancement or development of a form or state" within the context of BIM4VET maturity, this state is a quantification of an agent's ability in relation to BIM responsibilities and/or competencies. The unit of quantification utilised is the competence types discussed earlier. To express user ability, we must first create a context for linking the defined quantification. The model developed within this project defines a user as having 2 information sets associated with them. These sets represent:

1. The user's skills – a representation of the user's current ability within a defined set of possible responsibilities and/or competencies.

2. The User's Goals/Objectives – a representation of the ability a user wishes to reach via the application of training or experience.

User skills & objectives are quantified using 3 different forms; a profile, activity competence or base competence. These relationships are depicted in Figure 6 with a prefix stating the context of the relationship (either skill or objective) and the suffix stating the target type. From the relationships connecting profiles, activity competences, activities & competencies it is possible to infer user skills and objectives from axioms stated within each type. For example, an axiom stating a *skillProfile* in BIM author would allow a set of *skillResponsibilty* axioms to be inferred from the *hasResponsibility* relationships defined between BIM author and a set of activity competences. The same can be applied to the requirement relationship between an activity and a competency, to derive the competence in this case the competence level defined for the activity is applied as a set of Competences in the required competencies at the same level. The same inference can also be drawn between the set of objective axioms defined within the model.
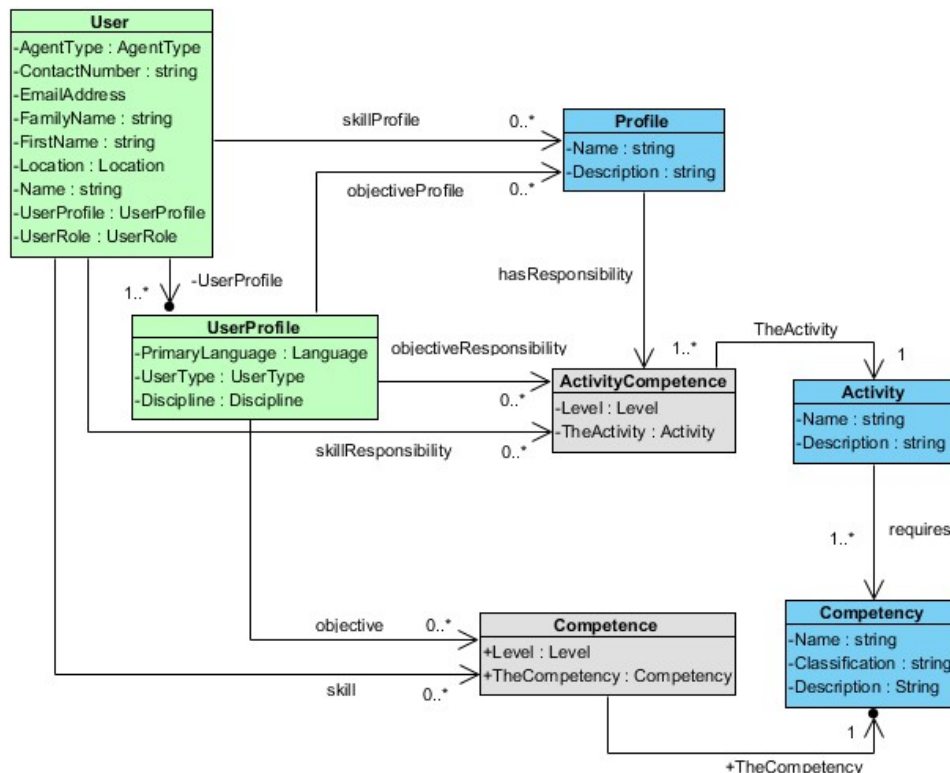
Figure 6 UML conceptual model representing user skills & objectives

A key structural decision that is apparent in Figure 6 is the separation of an individual's information into a *User* and *UserProfile* class where the subject of *skill* axioms is the *User* class and *objective* axioms is the *UserProfile* class. This separation is implemented for 2 reasons/situations. Firstly, it is defined that an individual can only have one unique skillset representing the individual's ability at the current point in time. Since an individual has a one to one relationship with an instance of the *User* class, it is logical to base all *skill* axioms from this class. Secondly, it is posited that an individual can define multiple objective sets for multiple purposes, for example different projects or professional development goals, hence a one to many relationships is employed between an instance of the *User* class and *UserProfile* class with the base for *objective* axioms placed here.

3.4.   Extrapolation to Organizational & Project Definitions

Within this research it is required that the definition of maturity be extended to cover projects and organizations. These entities in their simplest form represent a group of agents with a common goal or cooperative mission. An agent is an entity that does work within a system, and in a semantic sense is a supertype of the *Organisation*, *Project* and *User* classes. Inclusion within a group is represented by the membership axiom *MemberOf* (Figure 7). In a true semantic representation, the model would allow membership within a project or organisation to extend to any of the three agent classes, but in the context of the BIM4VET model this has been limited to an axiom between an organisation or project and a user. This structure is used because it drastically simplifies the model's structure and processing logic and represents most of the cases that exist in practice.
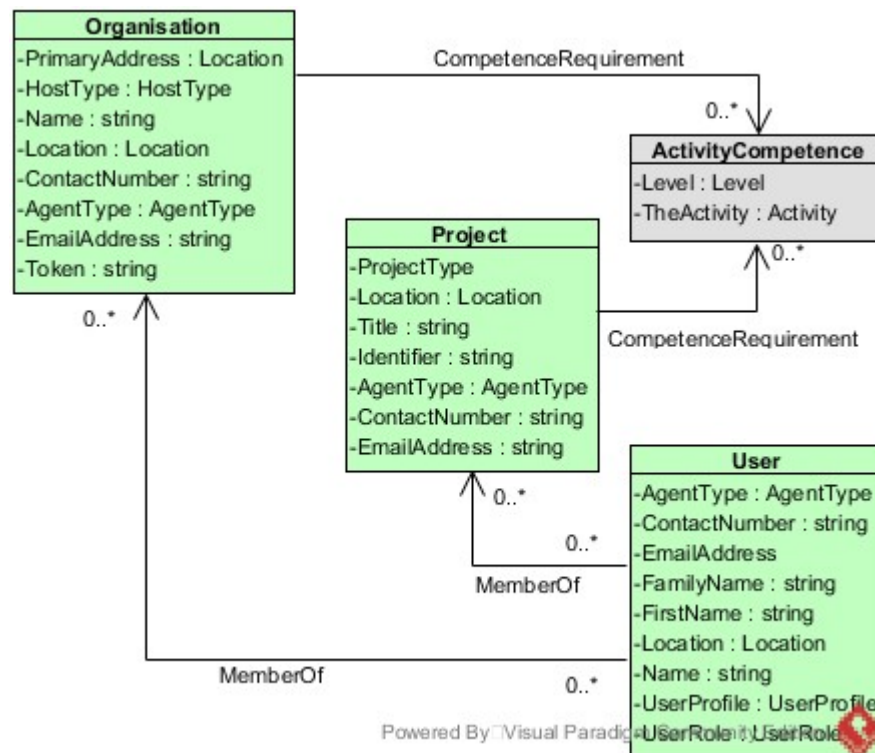
Figure 7 UML conceptual model of projects & organisations

Within the organisation and project definition an objective set and skill set like the user definition can be defined (Figure 7). The objective set is represented by a set of competence requirements allowing the definition of ability the group of individuals must collectively meet. To assess this collective ability, we must also be able to infer the collective ability of the group. The collective skill is derived by using a whole/part principle between the group and the individual,

the collective competence set is created by aggregating all the competences of the members together and then extracting the highest competence level achieved in each unique activity. The drawback of this technique is that it only represents the ultimate ability of the group rather than the collective ability. To represent the collective ability of the group it is proposed that the skillset of the group be represented as a pure aggregation organised as a set providing the quantities of unique competences within the group. This would then be able to illustrate both the ultimate ability and the depth of ability within the group.

3.5. Maturity Assessment Process

The Maturity assessment process developed so far within this project is made up of 2 actors: The user conducting the assessment and system providing computational support to the assessment inputs. The process is depicted in Figure 8 and descriptions of the steps are as follows for the User conducting the assessment:

1. Entry of User information – the first step is for the user to specify all relevant personal information the most important aspects are the location of the user (e.g. United Kingdom) and the languages spoken by the user. This information is required as part of the recommendation process of IO4 [see related deliverable for more details].

2. Course & Qualifications Completed – Next in conjunction with the repository of BIM training offerings the user specifies the courses and qualifications they have completed in the past, to generate their initial skill set.

3. Role Competences – next the user can specify their competence via the BIM role profiles that they are competent in to allow a section of competences to be selected using researched industry profiles with appropriate evidence to support the statement.

4. Activity Competences – Last, the user identifies any additional or higher competences in specific BIM activities to fully represent their skills and abilities.
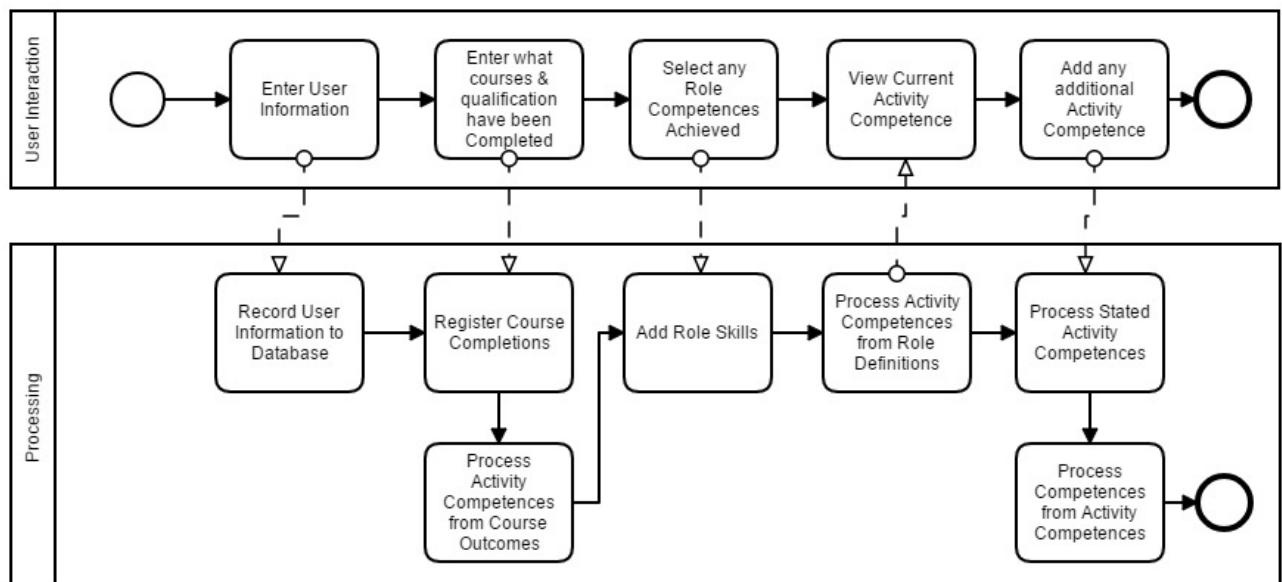
Figure 8 Diagram illustrating the maturity assessment process

As part of the process Figure 8 illustrates the various background processing tasks that are involved to extract the different competence representations from the user specified input. These tasks include the extraction of activity competences from the learning outcomes of

completed courses, the processing of Profile competences to update the relevant activity competences and the processing of all activity competences to associate the related base competences.

The Assessment process is based around a self-assessment methodology where a user can review their own skills and provide corroborating evidence to their ability. Further developments could be now explored around the validation and review of self-assessed competences.

4. BIM4VET Portal

4.1. BIM4VET Portal Overview

The BIM4VET Portal is an implementation of the framework for maturity assessment and includes functionality to store data sources from both the IO1 and IO2 outputs. The portal provides functionality for users to register their information, conduct their maturity assessment and additionally construct projects with user membership and competence requirements. The overall implementation architecture as depicted in Figure 9 is composed of 2 main elements, the BIM4VET Portal web application for user interaction and processing logic and the BIM4VET SQL database for storage and integrity of information relating to users, BIM profiles, activities, competencies and training. The system also has an auxiliary element to monitoring and diagnostics of the deployed system. The system is currently hosted and implemented using Microsoft Azure Cloud Services to streamline the development and hosting process. The application could eventually be moved and hosted on private infrastructure (e.g. infrastructure of BIM4VET partners or organization who wants to exploit the results).
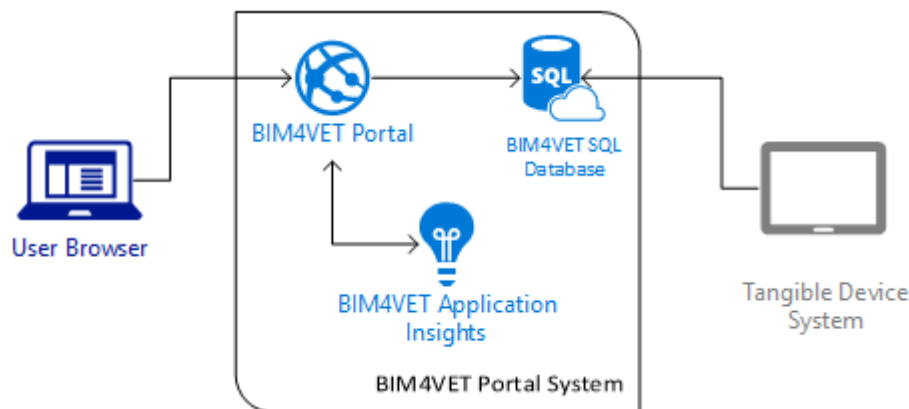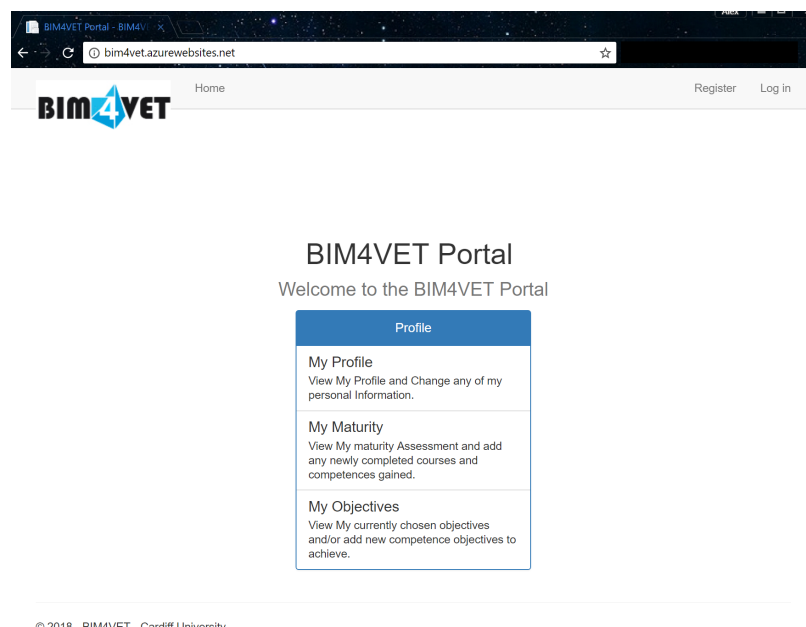

Figure 9 BIM4VET Portal Architecture Overview

Figure 10 BIM4VET Portal Home Page

4.2. BIM4VET Database

The database utilised within the system is a SQL database hosted within an instance of Microsoft SQL Server. Most of the data required for the operation of the entire BIM4VET implementation is stored within this database.

The database was defined by taking the BIM4VET framework conceptual model (entire model is depicted in Appendix I Figure 17) and developing it into an entity relationship model which is depicted by Figure 18, Figure 19 & Figure 20 in Appendix II. The entity relationship model implements many of the complex relationships defined in the conceptual model via relation tables (highlighted in orange), allowing the dynamic data related to Training instances and User maturity to remain independent of related information and to facilitate the numerous many-to-many relationships within the conceptual model. The Database model also adds functionality to track object state and store provenance information related to individual records.

4.3. Maturity Assessment

The Portal implements the maturity assessment process by means of 4 tabs, responsible for specifying completed courses, role profiles, responsibilities and competencies. Maturity levels are captured via single radio selection groups of buttons label 0 to 5, this selection is then sent back to the web server via an explicit update button. The processing logic of the web server is able then to update the specified competences as well as processing the relevant additional competences inferred from defined relationships. Images of the maturity assessment can be seen in figures 15-16.

4.4. Project Definition and Requirements

The last piece of functionality implemented by the portal is the ability to create project instances with project members and project competence requirements, these requirements are then able to be activity investigated and met via the use of the BIM4VET tangible interface by a project team to select and evaluate training combinations to meet the project requirements effectively. In future iterations it is expected to duplicate the functionality of the tangible interface into the online portal to expand the usability of the system.

Figure 11 BIM4VET Portal user information capture page

Figure 12 BIM4VET Portal user maturity overview and update page

Figure 13 BIM4VET Portal user maturity role competence specification page

Figure 14 BIM4VET Portal user maturity responsibility competence capture page

Figure 15 BIM4VET Portal user maturity base competence capture page

Figure 16 BIM4VET Portal project definition page

5.   Summary

Building Information Modelling (BIM) has emerged into the mainstream bringing a difference process of collaboration and a new way of working transforming current AECOO (Architecture, Engineering, Construction, Owner and Operator) industry structures and practices. With the need for new skills in the subject of BIM, the project Standardized Vocational Education and Training for BIM in the European Union (BIM4VET) addresses the need to standardize the quantification of skills provided by European training offerings, the representation of maturity for individuals, Organizations & Projects and development of a skills matrix for BIM Actor definitions.

This report addresses the need for standardized vocation training in BIM and the ability to both quantitatively assess maturity and set objectives for agents, by delivering a framework and implementation for the assessment of agent maturity for BIM based activities and practices. The framework for maturity assessment is a conceptual model and self-assessment process that provides the quantification of an agent's skills & objectives in relation to BIM activities, competencies and completed training.

The framework for maturity assessment is implemented by the BIM4VET Portal and includes functionality to store data sources from both the IO1 and IO2 outputs. The portal provides functionality for users to register their information, conduct their maturity assessment and additionally construct projects with user membership and competence requirements. The portal all acts as the first step in generating project specific training recommendation and professional development planning.

Possible future work to extend the initial prototypes developed in this research could cover the extension of the portal to include functionality to capture training offerings from course providers creating a centralised evolving repository for Europe. Additionally, the framework model could be improved to better accommodate repetitive and online-based courses by separating the training object into a Training definition and training instance reducing computational and storage load on the implementation system. Also, the further improvement of the assessment process and portal to all the validation and evidence-based review of user maturity is an area that needs to be addressed. Lastly, the extension of the portal to include the individual recommendation functionality of the tangible interface would generate more value for the system and encourage more training providers to submit their offerings to the central repository.

In conclusion, the developed framework and portal implementation has met the initial objectives focusing on maturity assessment of individuals and projects, and integrates well with the entire BIM4VET framework.

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Appendices

I. BIM4VET Completed Conceptual Model
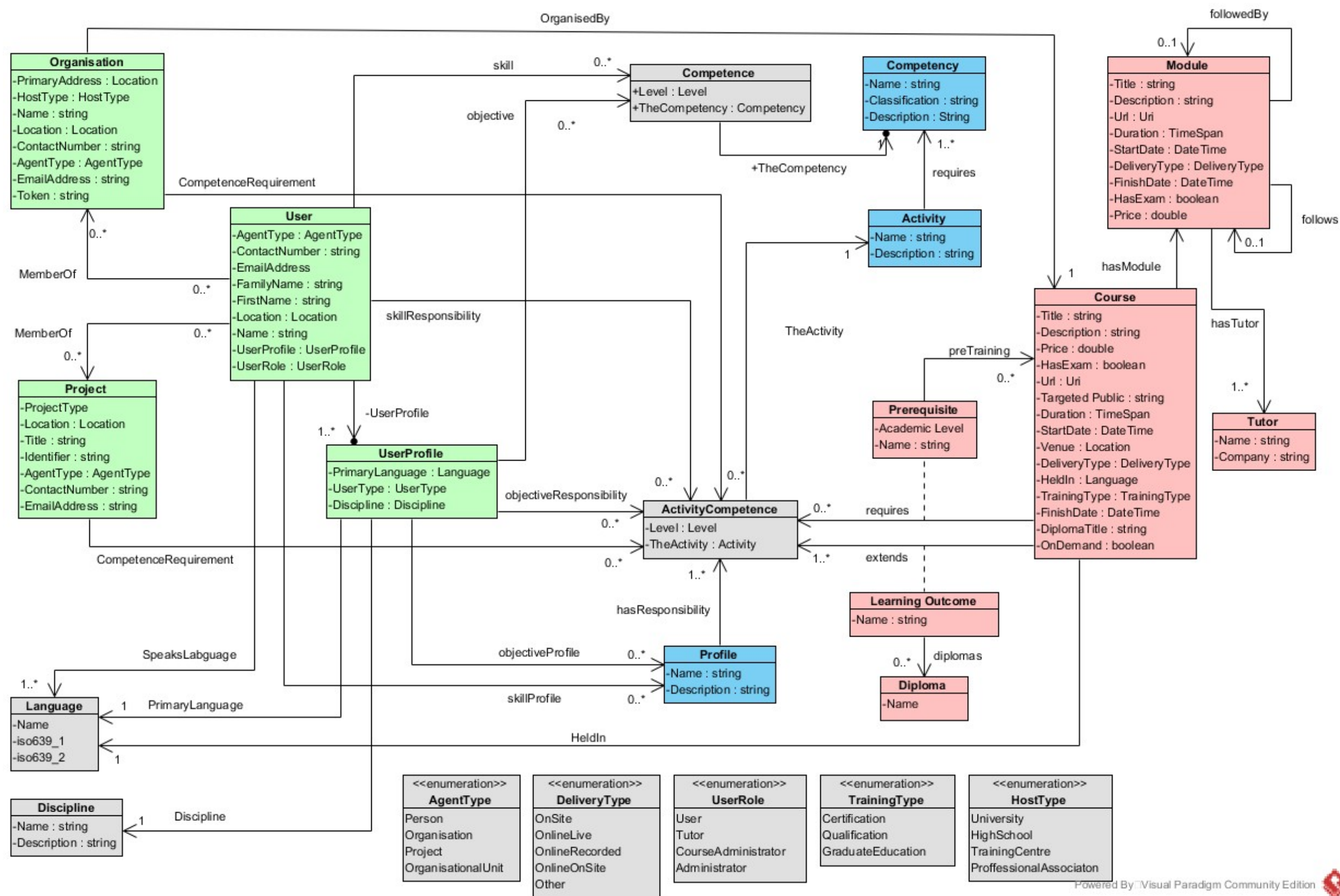
Figure 17 Complete UML conceptual model for BIM4VET

II. BIM4VET Complete Database Model

Figure 18 BIM4VET User Maturity database schema

Figure 19 Projects, Organizations & Users Model with Requirements

dbo.Location

Id	bigint
AddressLine	nvarchar(255)
AdminDistrict	nvarchar(255)
City	nvarchar(255)
CreatedBy	bigint
CreatedOn	datetime2
District	nvarchar(255)
LdUri	nvarchar(255)
Locality	nvarchar(255)
PostalCode	nvarchar(255)
Public	bit
State	int
UpdatedBy	bigint
UpdatedOn	datetime2
CountryId	bigint
BuildingName	nvarchar(255)

dbo.Organization

Id	bigint
AgentType	int
ContactNumber	nvarchar(255)
CreatedBy	bigint
CreatedOn	datetime2
EmailAddress	nvarchar(1024)
LdUri	nvarchar(255)
LocationId	bigint
Name	nvarchar(255)
Public	bit
State	int
Type	int
UpdatedBy	bigint
UpdatedOn	datetime2
Token	nvarchar(255)

dbo.CoursePrerequisite

RequiredCourseId	bigi...
ForCourseId	bigi...

FK_CoursePrerequisite_Course_RequiredCourseId

FK_Course_Organization_OrganizedById

FK_CoursePrerequisite_Course_ForCourseId

Relation Table

Seed/Static Table

Dynamic Tables

dbo.Tutor

Id	bigint
Company	nvarchar(255)
CreatedBy	bigint
CreatedOn	datetime2
FamilyName	nvarchar(255)
GivenName	nvarchar(255)
LdUri	nvarchar(255)
ModuleId	bigint
Public	bit
State	int
UpdatedBy	bigint
UpdatedOn	datetime2
UserId	bigint

FK_Organization_Location_LocationId

FK_Course_Location_VenueId

FK_Tutor_Module_ModuleId

dbo.Competence

Id	bigint
AtLevel	int
CompetencyId	bigint
CreatedBy	bigint
CreatedOn	datetime2
LdUri	nvarchar(255)
Public	bit
State	int
UpdatedBy	bigint
UpdatedOn	datetime2

dbo.CompetenceLearningOutcome

ForCourseId	bigint
CompetenceId	bigint

FK_CompetenceLearningOutcome_Course_ForCourseId

FK_CompetenceLearningOutcome_Competence_CompetenceId

FK_CompetencePrerequisite_Competence_RequiredCompetenceId

dbo.CompetencePrerequisite

ForCourseId	bigi...
RequiredCompetenceId	bigi...

FK_CompetencePrerequisite_Course_ForCourseId

dbo.Course

Id	bigint
CreatedBy	bigint
CreatedOn	datetime2
DeliveryType	int
Description	nvarchar(255)
FinishDateTime	datetime2
HasExam	bit
LanguageId	bigint
LdUri	nvarchar(255)
OrganizedById	bigint
Price	decimal(18, 2)
Public	bit
StartDateTime	datetime2
State	int
Title	nvarchar(255)
TrainingType	int
UpdatedBy	bigint
UpdatedOn	datetime2
Website	nvarchar(255)
DiplomaTitle	nvarchar(255)
OnDemand	bit
VenueId	bigint
Duration.Unit	int
Duration.Value	float(10)

dbo.ActivityCompetence

Id	bigint
AtLevel	int
CreatedBy	bigint
CreatedOn	datetime2
LdUri	nvarchar(255)
Public	bit
State	int
ActivityId	bigint
UpdatedBy	bigint
UpdatedOn	datetime2

dbo.ActivityCompetencePrerequisite

ForCourseId	bigi...
RequiredCompetenceId	bigi...

FK_ActivityCompetencePrerequisite_Course_ForCourseId

FK_ActivityCompetencePrerequisite_ActivityCompetence_RequiredCompetenceId

FK_LearningOutcome_ActivityCompetence_CompetenceId

dbo.LearningOutcome

ForCourseId	bigint
CompetenceId	bigint
Description	nvarchar(255)
Name	nvarchar(255)

FK_LearningOutcome_Course_ForCourseId

FK_Module_Course_CourseId

dbo.Module

Id	bigint
CourseId	bigint
CreatedBy	bigint
CreatedOn	datetime2
DeliveryType	int
Description	nvarchar(255)
FinishDateTime	datetime2
FollowedById	bigint
FollowsId	bigint
HasExam	bit
LdUri	nvarchar(255)
Price	decimal(18, 2)
Public	bit
StartDateTime	datetime2
State	int
Title	nvarchar(255)
UpdatedBy	bigint
UpdatedOn	datetime2
Website	nvarchar(255)
Duration.Unit	int
Duration.Value	float(10)

dbo.Language

Id	bigint
Iso639_1	nvarchar(2)
Iso639_2	nvarchar(3)
CreatedBy	bigint
CreatedOn	datetime2
LdUri	nvarchar(255)
Name	nvarchar(255)
Public	bit
State	int
UpdatedBy	bigint
UpdatedOn	datetime2

FK_Course_Language_LanguageId

dbo.Audience

Id	bigint
CreatedBy	bigint
CreatedOn	datetime2
Description	nvarchar(255)
LdUri	nvarchar(255)
Name	nvarchar(255)
Public	bit
State	int
UpdatedBy	bigint
UpdatedOn	datetime2

dbo.AudienceRelation

CourseId	bigint
AudienceId	bigint

FK_AudienceRelation_Audience_AudienceId

FK_AudienceRelation_Course_CourseId

FK_Module_Module_FollowedById

Figure 20 BIM4VET Database model for Training Repository

III. BIM4VET Profiles, Responsibilities & Competencies

BIM4VET Profiles

Table 2 BIM4VET Profiles

Profile	Description
BIM Author	No taught or earned knowledge relevant to the specified task
Senior BIM Author	Rigid adherence to taught rules or plans with no exercise of "discretionary judgement"
BIM Coordinator	Limited "situational perception" and all aspects of work treated separately with equal importance
BIM Manager	The ability to "cope with crowdedness" (multiple activities, accumulation of information), some perception of actions in relation to goals, adopts deliberate planning of task execution and formulates routines to recursively execute task effectively

BIM4VET List of Responsibilities

Table 3 BIM4VET Responsibilities

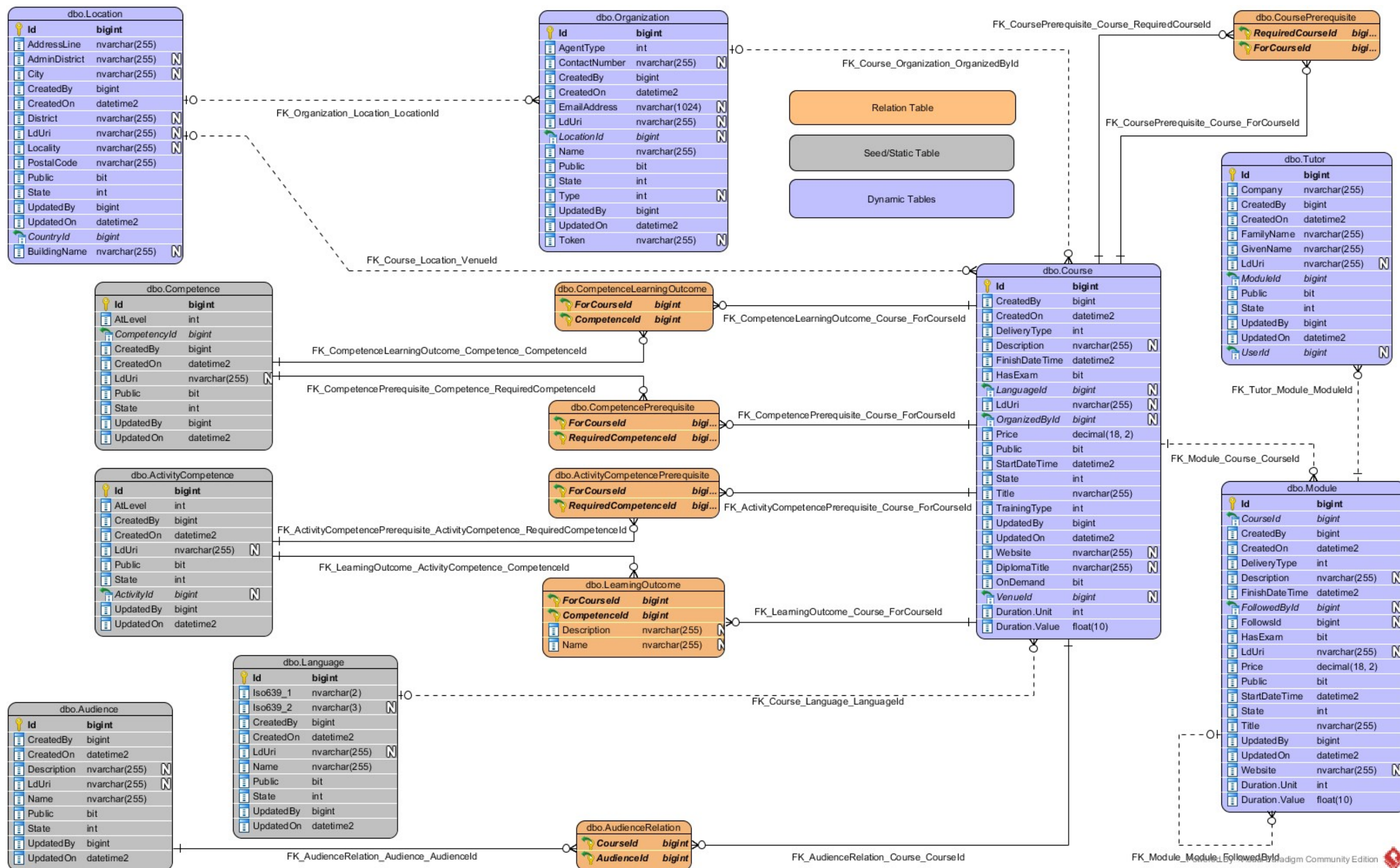| Activity	Description
Refer to work of team	Refer to the work done by other project team members
Develop models	Develop & maintain Graphical and Non-graphical models against Project Standards
Share models	Prepare model for sharing with internal and external stakeholders
Produce Project Outputs	Produce project outputs from graphical and non-graphical models
Revise Outputs	Revise outputs to incorporate clash resolution - Maintain a continuous interface with the BIM Coordinator - Participate in coordination and BIM technology meetings
Ensure Design Coordination	Reference of other shared models to ensure design coordination and clash avoidance
Ensure QA/QC Compliance	Revise Outputs regarding QA/QC protocols
Assist Project Standards	Assist in Maintaining Project Standards
BIM authoring supervision	Supervise BIM authors
Good Practice Watch	Remain fully UP TO DATE with Industry good practice around the production and exchange of Information
Maintain Internal CAD	Help maintain internal CAD standards and workflow by providing

Activity	Description
Standards	feedback to BIM coordinator
Project Standards Compliance	Ensure compliance to project standards
Corporate Standards Compliance	Ensure compliance to corporate standards
Inter/National Standards Compliance	Ensure compliance to relevant national and international standards
Coordinate BIM Outputs	Coordinate the different BIM Modeller/Technicians outputs to ensure the good quality and compliance of the model according to the BIM Project Execution Plan / BIM Protocol/client's requirements
Clash Resolution	Supervise Clash detection; reporting and resolution
Support Upskilling	Address immediate software issues and support the upskilling of staff
BIM Software Implementation	Ensure implementation of BIM software
Maintain Project Standards	Define & maintain project standards
Decide on Software Solutions	Agree software solutions to be implemented
Definition of Project Requirements	Define project outputs; according to the clients requirement
Coordinate Delivery	Create & maintain a coordination programme for delivery
Ensure Project Information Sharing	Ensure the implementation of a system to share project information
Lead BIM Activities	Lead BIM activities at project level
Assess Team Capabilities	Assess project team capabilities to comply with project standards

BIM4VET List of Competences

Table 4 BIM4VET Competencies (extract from [12])

Management Set

Identification		Definition
M01	General Management	Defining and communicating overall managerial goals from adopting new systems and workflows
M02	Leadership	Leading and guiding others throughout the process of implementing new systems and workflows
M03	Strategic Planning	Identifying strategic objectives and developing implementation strategies
M04	Organizational Management	Identifying the organizational changes necessary for instigating, monitoring and improving BIM Adoption
M05	Business Development & Client Management	Maximizing the value achieved by the organization and its clients from BIM tools and workflows
M06	Partnership & Alliancing	Initiating partnerships and alliances with other organizations based on BIM Deliverables and workflows

Administration Set

Identification		Definition
A01	Administration, Policies & Procedures	Developing managerial initiatives into policies and procedures to facilitate the adoption of BIM tools and workflows
A02	Finance, Accounting & Budgeting	Planning, allocating and monitoring the costs associated with BIM Adoption
A03	Performance Management	Assessing organizational BIM capability/maturity, Individual Competency and project performance using standardized metrics
A04	Human Resource Management	Planning, developing and managing human resources as to align staff competencies to organizational BIM goals
A05	Marketing	Promoting an organization's BIM Capability to its clients and business partners
A06	Tendering & Procurement	Developing the necessary specifications and documents to pre-qualify, recommend or procure BIM products and services
A07	Contract Management	Administering the contractual documentation underlying Collaborative BIM Projects and workflows
A08	Risk Management	Managing the risks associated with using BIM tools and collaborative workflows
A09	Quality Management	Establishing, managing and controlling the quality of models, documentation and other Project Deliverables

Functional Set

Identification		Definition
F01	Functional Basics	Identifying the basic requirements and main deliverables expected from using BIM tools and workflows
F02	Collaboration	Preparing the documentation necessary to enable Model-based Collaboration between Project Participants
F03	Facilitation	Facilitating the process of BIM collaboration between Project Participants
F04	Project Management	Managing projects where BIM Workflows are used, and BIM deliverables are specified
F05	Team & Workflow Management	Managing teams involved in the delivery of BIM Projects

Operational Set

Identification		Definition
O01	General Modelling	Using software tools to model project requirements and generate Model-based Deliverables across industries, information systems and knowledge domains
O02	Capturing & Representing	Using software tools and specialized equipment to capture and represent physical spaces and environments
O03	Planning & Designing	Using software tools for conceptualization, planning and design
O04	Simulating & quantifying	Using software tools to conduct various types of model-based simulations and estimations
O05	Constructing & Fabricating	Using BI Models for the specific purposes of construction and fabrication
O06	Operating & Maintaining	Using models to operate, manage and maintain a Facility
O07	Monitoring & Controlling	Using models to monitor Building Performance or control its spaces, systems and equipment
O08	Linking & Extending	Linking BI Models and their components to other databases
O09	Custom Modelling	Using software tools to deliver a custom combination of Model-based Deliverables reflecting a variety of Model Uses

Technical Set

Identification		Definition
T01	General IT	Installing, managing and maintaining general IT infrastructure
T02	Software Systems	Selecting, deploying and maintaining software systems in a multi-user environment
T03	Hardware & equipment	Specifying, recommending or procuring computer hardware and equipment
T04	Modelling	Generating BI Models based on pre-defined Modelling Standards and protocols
T05	Documentation	Generating drawings and construction documents using standardized details and workflows
T06	Presentation & Animation	Generating professional-quality renderings or 3D animations using Specialized Software Tools
T07	Model Management	Managing and maintaining BI Models generated using standardized processes, protocols and specifications
T08	Document Management	Using Document Management Systems or like store, manage and share files and BI Models

Implementation Set

Identification		Definition
I01	Implementation Fundamentals	Identifying and managing issues associated with BIM implementation
I02	Component Development	Implementing a structured approach for developing or customizing Model Components using documented Modelling Standards
I03	Library Management	Developing or managing component libraries as required for the standardized delivery of BIM Projects
I04	Standardization & Templates	Generating standardized templates, item lists and workflows for initiating, checking or delivering BIM Projects
I05	Technical Training	Developing a BIM Training Plan or maintaining a Skill Register to track staff training and their acquired skills
I06	System & Process Testing	Assessing the capability/compatibility of systems and the suitability of workflows and procedures
I07	Guides & Manuals	Developing guides, manuals or educational material covering Model based Workflows

Supportive Set

Identification		Definition
S01	*General IT Support*	Troubleshooting software issues and supporting staff in resolving technical problems
S02	*Data & Network Support*	Managing and maintaining the storage of data, documents, 2D Drawings and BIModels
S03	*Equipment Support*	Developing specifications for BIM Hardware and BIM Hardware Deployment Programmes
S04	*Software Support*	Addressing issues related to BIM Software Tools, fulfilling relevant Support Tasks and managing the relationship with software vendors/resellers
S05	*Software & Web Development*	Developing extensions for BIM Software Tools, productivity software or web portals to improve BIM Deliverables

Research & Development Set

Identification		Definition
R01	*General Research & Development*	Conducting general or BIM-specific research and development activities
R02	*Strategy Development & Planning*	Developing a BIM Implementation Strategy or a BIM Implementation Plan to guide BIM Adoption
R03	*Teaching & Coaching*	Developing BIM training material to educate staff and facilitate the BIM Adoption process
R04	*Knowledge Management & Engineering*	Developing a Knowledge Management Strategy and capturing/representing the BIM-specific knowledge of staff
R05	*Change Management*	Developing a Change Management strategy that accompanies/supports the BIM Implementation process
R06	*Research & Analysis*	Participating in and/or publishing academic research focused on BIM innovation or collaboration
R07	*Industry Engagement & Knowledge Sharing*	Sharing BIM knowledge and experience with the wider industry through formal/informal workshops, seminars and presentations

IV. BIM4VET Taxonomy of Terms

Term	Synonyms	Description
Agent		An agent is a thing that bears some form of responsibility or participation for/in an activity or action taking place, for the existence of an entity, or for another agent's activity.
Competence	Capability;	A Competence is a statement of the level of skill.
Competency	ability; skill;	A Competency is a Defined Skill.
Discipline		A branch of knowledge within the domain of engineering.
Level	Metric; Grade;	A Position on a scale representing amount extent, quantity or quality.
Skill Level	Competence level;	A position on a scale measuring the knowledge, expertise or ability to conduct a defined Competency.
Fit Level	Match Level; Suitability level;	A position on a scale measuring the fitness or suitability of a training course to fulfil the user's stated Objective Set.
Training	Course; Workshop; Seminar;	A Defined curriculum of learning objectives, materials, classes and/or lectures that provide additional knowledge and ability to the participant. These training courses can be via e-learning platforms, in person seminars, lectures or workshops, or academic qualifications. Courses have a defined set of Prerequisites and outcomes which on completion are transferred to the Participant (User).
Tutor	Instructor;	An agent who is responsible for delivering a Training course.
User		In reference to the BIM4VET Data model a user is an individual person who has a defined Skill Set & Objective Set.
Skill Set	Capability set;	A Skill Set is a collection of Competences (defined under the Concept of Competence) that defines an agent's (people and/or organisations) current ability levels achieved and validated through previous training courses, professional roles undertaken, and explicit competence statements.
Objective Set	Competence objectives; Skill objectives; Capability objectives;	An Objective Set is a collection Competences (defined under the Concept of Competence) that defines an agent's (people and/or organisations) Goal to be reached. These goals can be based on Competence requirements for generic industry project roles, client defined specialist roles or explicit competency items.
Prerequisite		A prerequisite is the minimum competence/s required prior to the undertaking of a training course. The Prerequisites can be defined as other specific training courses or individual explicit competences.

Outcome	Result;	An outcome is the resultant Competence/s that are gained from the undertaking of a training course. These will then be translated into the User's Skillset. Outcomes allow the attachment of additional certification definitions such as diplomas, degrees or institutional certifications.
Role	Profile; Task profile;	A Role in its simplest represents a meaningful collection of rights and responsibilities set out to assume a defined function.
Responsibility	Task assignment;	A responsibility is the conceptualisation of the Nary relationship between an Agent or Role and an Activity. The responsibility defines the assignment/requirement of the Agent (or the Agent assigned the Role) to complete the specified activity. In the context of BIM4VET this implies that the agent requires/has the Competence to complete the associated Activity
Activity	Task; Action	An Activity is a thing that an agent has done, will do or is currently doing. Activities can be atomic consisting of a single operation carried out on a thing, or a collection of actions/task that are grouped or sequenced to fulfil a defined function or objective. In the Context of BIM4VET activities define minimum competences that are required for their effective completion. this allows an agent's capability to complete an activity to be evaluated by the comparison of the activity's competence requirement and the agents skill set.
Requirement		A requirement is the definition of a mandate to satisfy a defined criterion, such as the completion of a task, the inclusion of information or the meeting of a minimum competence. Requirements can be refined by additional application, selection and exclusion statements. (See RASE Technique for Requirements capture and definition).

BIM4VET Partners

LIST / Luxembourg Institute of Science and Technology	LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY | LIST
Cardiff University	CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD
LIST / CEA tech / Commissariat à l'Energie atomique et aux énergies alternatives	list cea tech

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