Project Management Methodology for the Development of M-Learning Web Based Applications

Adrian VIŞOIU
Academy of Economic Studies, Bucharest, Romania
adrian.visoiu@csie.ase.ro

M-learning web based applications are a particular case of web applications designed to be operated from mobile devices. Also, their purpose is to implement learning aspects. Project management of such applications takes into account the identified peculiarities. M-learning web based application characteristics are identified. M-learning functionality covers the needs of an educational process. Development is described taking into account the mobile web and its influences over the analysis, design, construction and testing phases. Activities building up a work breakdown structure for development of m-learning web based applications are presented. Project monitoring and control techniques are proposed. Resources required for projects are discussed.

Keywords: *Software Project Management, M-Learning Applications, Web Applications, Methodology*

1 Introduction

M-learning is an educational process based on mobile technologies. M-learning as a concept is practically implemented via m-learning applications. Developing an m-learning application is a complex task. Educational, technological and management elements are taken into account when developing an m-learning application is established as an objective. In higher education institutions there are research centers that deal with research projects, such that organizational infrastructure is fit to a project type approach. A common development approach for m-learning applications is organizing all the activities under the form of a project. The project has as objective delivering a working m-learning application. In the project numerous people are involved. Teachers, students, analysts, designers, developers collaborate in the project team. Numerous types of material resources are involved.

A dedicated project management is required for specific elements of this type of software development. Further, mobile application development has many directions. Project management, as well as specific tasks vary with the type of application that is intended to obtain. This paper covers the problem of project management for web based m-learning applications.

2 M-Learning Web Based Applications Characteristics

M-learning web based applications are a very particular case found at the intersection of three categories of applications: e-learning applications, mobile applications and web applications.

Mobile applications are applications designed to run on mobile devices like smartphones. Compared to applications that run on personal computers, there are differences regarding the development technologies and also important hardware differences. Considering the architecture, there are similar classifications:

- web based/distributed applications accessible via web browsers;
- client – server applications where certain aspects of the application run natively on the device and other modules are addressed remotely;
- standalone applications that run entirely on the device.

Web applications are applications that are accessed over the Internet or intranet. The common structure of a web application consists of tiers. The presentation tier resides on the client web browser that renders the user interface. The functionality and the application logic reside at the second tier, called business tier, on the web/application server

running a dynamic content generation engine. The third tier is the storage tier residing on a database server. When interacting with the application at client level, data containing both required information and commands are posted from the web page to the web server. At web server level, queries are run against the database server to retrieve useful information for the user. The retrieved information is processed on the web server using the dynamic technologies like ASP.NET, JSP or PHP. Processing results are stored back into the database or presented to the user via dynamically generated web pages.

Advantages of web applications are:
- they do not require following special installation procedures on client machines; installation and configuration is done on the necessary servers;
- the client has little performance requirements as all the intensive processing is distributed to the web/application server and database server;
- any change/patch/upgrade in the product is reflected to all clients instantaneously without effort;
- they are accessed via a web browser; web browsers implement industry standards, web applications being compatible with all operating systems;
- users that commonly use web browsers will easily accept such application.

Disadvantages of web applications are:
- the weak link is the connection between the client and the web server and also the connection between the web/application server and the database server; each of these components is placed remotely one from another and an unavailable connec-

tion leads to interruptions in work;
- security problems related to information transport over the networks and user activity tracking;
- scarce interfaces due to the web limitations; there are ways of improving interfaces' look but any complicated approach is subject to compatibility problems as certain features are not implemented the same way on different web browsers.

M-learning applications refer to software intended to support learning process using the mobile technologies. If mobile devices like smartphones are taken into account then m-learning applications are likely to become widespread as the number of devices having important processing capabilities rises.

Advantages of m-learning applications include:
- student's contact with new technology;
- easy carrying everywhere as opposed to a laptop/desktop computer;
- collaboration between students; m-learning applications encourage students to contribute with content and give feedback on content;
- they are motivational for students if they have game like approaches;

There are also many aspects that have to be overpassed, aspects the come from the device characteristics:
- device's batteries run out;
- the devices have small screen for viewing;
- small storage space compared to a PC;
- device processing power is small.

The intersection between the types of applications that give birth to m-learning web based applications is presented in Figure 1.
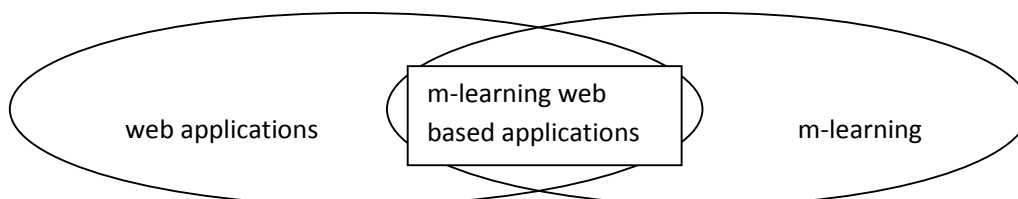

Fig. 1. The place of m- learning web based applications

Developing m-learning applications is where mobile developers and teachers come in con-

tact. Solid mobile development is required to obtain high quality software in this particular

environment. The Web content is standar-dized by markup languages, styles, scripts and multimedia, all these being viewed using web browsers.

There are differences between the mobile web and desktop web as presented in [1]:

- there are markup languages and styles specific for mobile devices;
- different MIME types;
- browsers differ in capabilities;
- network proxies that adapt content.

The context of m-learning web based appli-cations is given by:

- small screen sizes;
- small resolutions;
- browser bugs;
- ignored standards;
- available languages: XHTML, HTML, XHTML Mobile Profile, CHTML, WML;
- Javascript and AJAX, not on all the phones;
- browser plugins; not all browsers support or implement the same way.

The web browsers differ in functionality:

- Internet Explorer (Windows Mobile) – markup support: HTML 4.01, XHTML 1.0 and 1.1, XHTML MP, XHTML Basic; style support: CSS 2.1, CSS mobile pro-file 1.0, Wireless CSS 1.1; scripting sup-port: Jscript 5.6, DOM 1 and partially 2 and 3, AJAX; AJAX is handled via Acti-veX object Microsoft.HMLHTTP not Ja-vaScript's XMLHTTPREQUEST; also has ActiveX objects and Flash support;
- Opera Mini/Mobile (J2ME/platform spe-cific); markup support: XHTML 1.0, HTML 4.01 and partially 5, WML 1.3; style support CSS 2 and 3; scripting sup-port JavaScript, DOM 2, AJAX; Flash plugin;
- BlackBerry browser; implements mobile web standards: XHTML-MP, WML, Wireless CSS, HTML 4.01, DOM 2, Ja-vaScript, AJAX;
- Nokia Browser; Based on WebKit brows-er; supports XHTML, JavaScript AJAX, Flash plugin;
- Android Browser; based on WebKit browser; supports web standards;
- Safari for IPhone; WebKit based browser;
- Generic WebKit browser; open source project implemented on many platforms; supports HTML 4.01, XHTML 1.0, par-tially HTML 5; styles: CSS 2.1, partially 3; scripting JavaScript, AJAX, DOM 1-2-3.

M-learning applications are intended to offer functionality both to students and teachers.
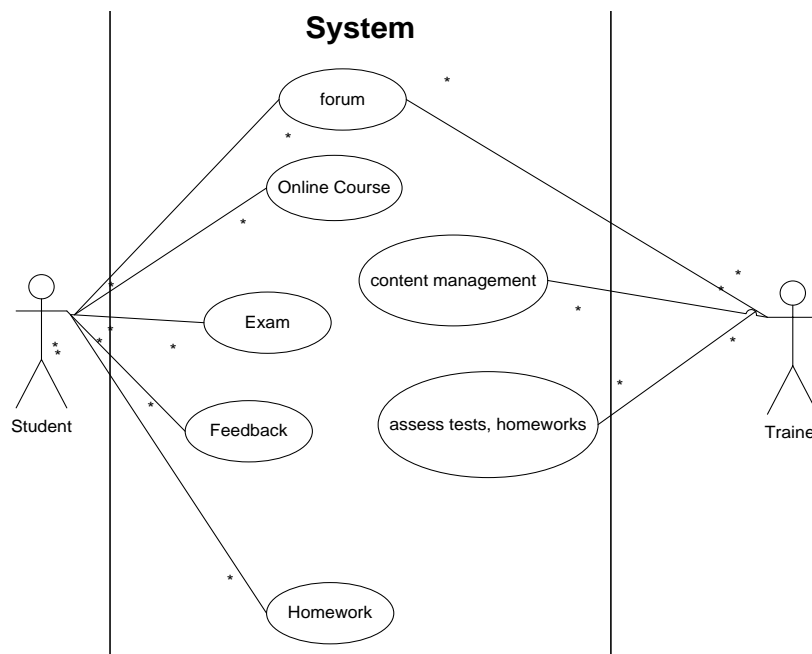

Fig. 2. Use case diagram for an m-learning application

Figure 2 shows the use case diagram for an m-learning application containing top level

use cases that reflect general functionality of m-learning applications.

The administration of the m-learning applications is achieved via a content management system. The content management system is structured into modules:

- online courses/lessons; lectures and seminars as study material that has to be accessed by the students;
- assignments; there are deadlines for assignments; teacher adds notes received assignments giving feedback to students; resubmission is possible;
- chatting; permits a direct contact between teachers and students;
- forum; permits offline interaction between the study group;
- quiz/test; offers testing and functionality;
- wiki; collaborative environment where everybody contributes with information on relevant subjects.

The m-learning web based application is a complex content management system. Modules are developed according to priorities. First the online course/lessons is developed. Assignments and tests follow. These cover the main aspects needed for learning. Then forums and wiki's are developed to round up the image of a complex m-learning application.

An important aspect of an m-learning application is security. The application is accessed by many users. Users have different roles. Students may read course information freely. Course information is added only by teachers. The students submit assignments. They must be correctly identified. Also only teachers can see submitted assignments. The notes the teacher adds to assessed assignments can be seen only by the corresponding student.

As seen above, the functionality of the application is put in correspondence to user roles such way a certain role has limited access to information. This part covers security authorizations. Further, a proper identification of users must be done in order to ensure that an authenticated user is the person it pretends to be. A classical approach is the use of a username and password. We are not discussing here the problems associated to network traf-

fic security and required encryption. Strictly form usability point of view, this approach is difficult as the screen size is small and available keyboards are difficult to operate even on touch screen devices. Also, a non QWERTY keyboard requires many pressings to obtain a character, leading to high probability of wrong login data to be entered. On some devices, the letter pressed in a password field is shown for a small time reducing input errors but increases the probability of password interception. An improvement for the username password technique is the use of additional questions having personal information required. Personal information is stored securely in the application database or taken from the institution's database and a random question is put.

Best practices for web application security suggest:

- working with no cookies;
- passing session id in URL;
- usage of security certificates and HTTPS protocol for authentication.

These security elements are placed at mobile browser – web server interaction. Further security regards stored information. The database contains sensitive information such as:

- account information;
- personal information;
- students' marks;
- submitted assignments;
- test and quizzes questions and answers;
- history of taken tests and exams for each student.

Each of these elements may be subject to unauthorized access. Security measures must take care of the following aspects:

- data integrity; protect the existing data from intentional or accidental corruption; keeping the integrity of submitted assignments is useful as they prove that the student accomplished assigned tasks and received marks or points for the work done; every mark given by a teacher needs a support to be assessed and every student that sent his assignment needs to be sure that submitted information is not lost and will be subject to evaluation; the same procedure applies to exams as well;

- protection against unauthorized access; if database is read by unauthorized persons such way that table definitions, table data are visible, sensitive information must not be understandable to such attackers; the solution is to keep sensitive data encrypted; account information such as username and password may be stored as hashes; sensitive personal information is subject to encryption using recommended standards;
- backup; the database has to be backed up on a regular basis; in case of incidents, database content must be recovered rapidly such way the educational process is not affected.

Security measures do not apply only to static aspects of the web application. Security procedures must address complex activities such as exams. When taking exams, the following aspects must be covered:

- identity of the examinee must be established;
- access to course information must be blocked; when a student is logged in to the application in exam mode access to study resources is automatically blocked; this is a feature of the m-learning application; further access to other network resources must be limited by the network administrator; if the exam takes place in a classroom, then the wireless router is configured to permit access only to the m-learning application server; this latter feature is not opposable to the application, but is covered at institutional level;
- ensuring exam consistency; all the examinees must submit a variant of the answers, either intentionally or automatic submit at expiration time;
- non-repudiation – once submitting the answers the examinees cannot negate their actions and answers to the questions.

3 Project Management Cycle

The project management of m-learning web based applications takes into account the peculiarities of such applications.

In order to create a work breakdown structure for m-learning web based applications, an inventory of the work packages or tasks from the literature is done.

- in [2] there are presented: research, scriptwriting, implementation, validation, project management, testing, closing, lessons learned;
- in [3] there are presented: planning, design, construction, testing, documentation, deployment;
- in [4] there are presented: project management and implementation, planning and concept, design, construction, testing, implementation and closing.

As seen above, there are common work packages with other software projects. The differences come into light when looking at the specific tasks for each work package.

Project management work package is a main component of the WBS. This work package consists of tasks that cover the whole duration of the project. These tasks are the following, as presented in [5]:

- project initiation;
- project planning;
- project execution;
- project monitoring;
- project closing.

Other work packages and tasks cover aspects both of the m-learning field and web development.

Documentation is a work package containing the activities needed to obtain the content that later fills the application. The tasks for documentation are:

- researching relevant bibliographic sources; the outcome is the list of identified relevant sources;
- elaboration of study materials: includes courses, seminar support, homework; the outcome is the electronic content with the mentioned elements;
- elaboration of tests; includes questions and answers, thresholds, reward points.

Documentation obtains all the materials needed to run the discipline and later to be introduced in the application.

Analysis is a work package grouping tasks related to obtaining a clear description of what has to be done. The tasks are:

- business model; this describes how the

learning activity takes place;
- requirements specification; what are the requirements for the application; the requirements include functional requirements regarding the logic of the application and non-functional requirements related to: technical restrictions, security requirements, interface requirements, product quality characteristics.

Results of the analysis are reports containing the best and recommended approaches.

Design is a work package grouping tasks related to the definite way the application will be built. Related tasks are:
- website design; includes the structure as a sitemap;
- interface design; each page is designed in terms of areas and controls; design fulfill mobile web standards and address mobile restrictions that represent a peculiar feature of these applications; also design must be in concordance with specified quality characteristics of usability and readability as defined in requirements;
- database design is a task which is independent from the type of application;
- detailed use cases; each functionality is detailed to highlight the algorithms that lead to obtaining significant results for users; further those algorithms will be translated into code in the next phases;
- storyboard; a nonfunctional prototype is built to create an actual representation of the product.

For designing the site structure, some elements are taken into account:
- users that access the site; the context of accessing – teaching, exam, homework;
- target devices; is the institution endowed with mobile devices all of a kind for certain classes or the application is meant to run on personal mobile devices which have different characteristics;
- tests must be done using XHTML to obtain the look and feel of the final product.

At design time there are established:
- technologies used;
- programming languages;
- multimedia elements;
- database systems;

- devices needed;
- hosting requirements.

The result of finishing the design work package is a structure ready to be implemented. After everything is known in detail, acquisitions are made.

Acquisition work package deals with obtaining the material support to run the project. Tasks include:
- hosting acquisition; if it is decided that the application is hosted on external servers, then a hosting plan must be bought;
- materials acquisition; the necessary materials needed to implement the application are: mobile devices, if the objective is to built a class based on m-learning, then devices must be available to all students; network elements, such as, routers, cables and other materials identified as necessary for implementation;
- licenses acquisition; if in the design phase it is decided to use proprietary software, licenses must be acquired.

Construction is a work package containing tasks related to the actual translation of the design into a real working product. Tasks for construction are:
- database creation; the design model is implemented on a database server;
- application development: includes interface development, server side development;
- database populating; the content developed in documentation stage is inserted into the database;

Construction gives a working application.

Testing is a work package containing tasks related to checking that the product is in conformity with the specifications and works correctly. Tasks are:
- detail testing; as the modules are developed they are tested for correctness in a standalone manner;
- ensemble testing; the application is tested as a whole, in lab conditions, on phones or phone emulators;
- user testing; the application is tested by the actual categories of users that come in contact with it: small groups of students and teachers; this testing must cover as

many mobile devices as possible such way to reduce the probability of encountering devices that are not compatible with the application.

In testing both device emulators and actual devices are used. Emulator testing and development has both advantages and disadvantages:

- development environments are easily integrated with device emulators;
- emulators cover the major functionality of a real device; this includes operating system, built-in applications; third-party applications; phone functionality is covered via instruments that simulate a telephony network and allow fake phone calls, messages;
- emulators are easily configured for internet/intranet access;
- testing critical applications is harmless as any destructive change to the emulator can be undone via hard reset;
- some functionality is unavailable on emulators; for example, on some platforms Bluetooth development cannot be done on emulators as Bluetooth functionality is not supported; the respective vendors encourage development on real devices;
- the crucial debug-on-device feature is available both on emulators and real devices for the main development platforms;
- emulators are operated via computer inputs which differs from real life usage;
- complex interface and sensor support cannot be reproduced on emulators on development PC; multi-touch screens, multi-

touch gestures, accelerometer gestures, continuously changing GPS position are elements difficult to implement or test on an emulator;

- not in the last place, emulators are mainly free as devices with high capabilities are very expensive.

Implementation and closing is a work package related to transferring the working application in the real environment. Tasks include:

- application deployment; the application is published from the production server to the public server; settings are changed accordingly;
- database deployment; the database is published on the public server;
- training; teachers and students are trained to use the application; if quality requirements are specified according to mobile world restrictions with emphasis on usability, readability, simplicity training is easy as the application is accepted by the users;
- closing; if all phases ended successfully the project is terminated with positive review.

All these work packages are gathered in a general work breakdown structure for m-learning web based application projects as presented in Figure 3.

Further, each of these identified tasks is divided in subtasks. This level of granularity is specific to each project as some activities have different priorities given different requirements.
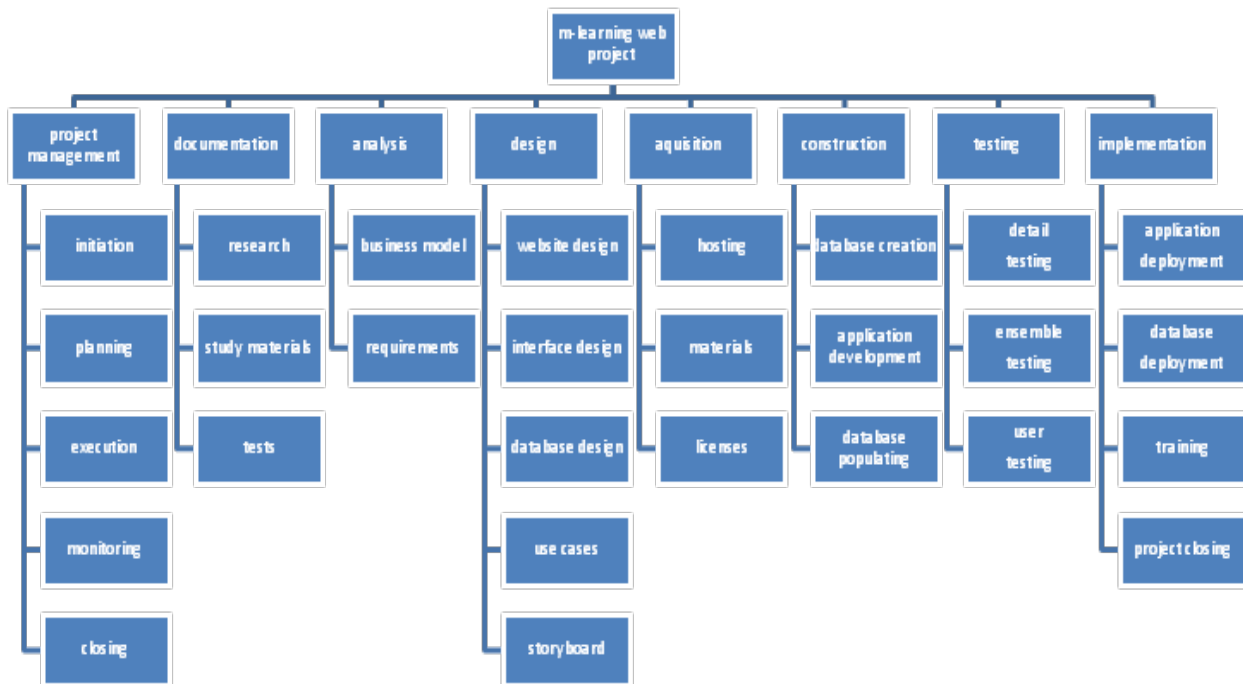
Fig. 3. General WBS structure for m-learning web based application development

Dependencies are identified between tasks. The activities are considered nodes in a graph associated to the project. Taking into account planned start and end dates, critical paths and time reserves are to be found. The critical path gives the manager the axe of activities where to pay attention as any delay leads to falling behind scheduling for the whole project. Time reserves show the manager what activities may be delayed such way the end date of the project is not affected.

4 Progress Measures

Measuring the project progress is a continuous task. The project plan establishes tasks, durations, resources, costs and performance criteria for the work done. When running the project certain deviations from the plan appear. The project manager has to take corrective actions to avoid losses in terms of money, resources or time.
Monitoring and controlling the project consists of:
- assessing current project status
- comparing planned with actual values;
Results of monitoring are:

- rescheduling the project; when some tasks are behind schedule;
- re-budgeting;
- re-assignment of staff and resources.

Objective measures are recommended for a successful project monitoring and control. Such a method is the Earned Value Management. To implement the method there are necessary: a project plan, a valuation of planned work and quantification of accomplished work. Consider the tasks A_1, A_2, …, A_n, building up project P, the earned value, the planned value of the project, at a moment t is:

$$PPV(t) = \sum_i PV(A_i), \text{ planned\_end}(A_i) < t,$$

where
PPV – the planned value of the project;
$PV(A_i)$ – the planned value of task A_i;
planned_end(A_i) – function returning the planned end time of A_i task.
The earned value of the project at moment t is

$$PEV(t) = \sum_i PV(A_i), \text{ actual\_end}(A_i) < t,$$

where

PEV – the planned value of the project;
$PV(A_i)$ – the planned value of task A_i;
$actual\_end(A_i)$ – function returning the actual end time of A_i task.

Also, another indicator comes in to enlarge the analysis area, the actual cost:

$$PAC(t) = \sum_i AV(A_i), actual\_end(A_i)<t,$$

where
PAC – the actual cost of the project up to moment *t*;
AV – actual value to complete task A_i;
$actual\_end(A_i)$ – function returning the actual end time of A_i task.

Based on these indicators, other measures are derived to interpret project status. The project scheduled variance PSV is computed as:

$$PSV = PEV-PPV.$$

The project cost variance is computed as:

$$PCV = PEV- PAC.$$

If PSV is positive then the project is ahead schedule. If PCV is positive then costs were under budget.

Also another set of indicators is derived. The Schedule Performance Index, SPI is

$$SPI = PEV/PPV.$$

The cost performance index is

$$CPI = PEV/PAC.$$

Positive interpretations arise when SPI>1 and CPI>1.

Monitoring these indicators at certain moments of time the project manager may tell whether the project fell behind schedule or not, whether the project was under budgeted or not.

Beside the financial point of view there are indicators showing progress of individual tasks. For development stage progress may be assessed by indicators taking the form of:

$$DI = DM/TM,$$

where
DI – application's degree of implementation;
DM – number of developed modules;
TM – total number of modules.

The DI indicator shows what fraction of the implementation activity is finished.

In a similar manner, in testing phase, when dealing with applications designed to run on various platforms, the degree of portability testing, DP, has the form:

$$DP = NTP/TNP,$$

where
DP – degree of testing for portability;
NTP – number of tested platforms;
TNP – total number of platforms.

Accordingly, indicators are built for each phase or work package. Indicators must be built such way that:
- they reflect correctly the aspects undergoing analysis;
- they are easy to interpret;
- data collection is straightforward, without burdening the project work;
- the mathematical expressions are simple.

Project monitoring and control is efficient only if the manager not only looks at performance indicators but also if corrective actions and decisions are taken to lead to accomplishments of established objectives.

5 Resource Allocation, Costs and Risks

Many resources are necessary to complete an m-learning project.

Regarding human resources, the project manager has to build a team where roles are well defined. The common roles in a team, taking into account the peculiarities of the m-learning web application project management are:
- chief writer: the person who decides what the content must contain; it the higher education can be the chief of the discipline the application is developed for;
- technical writer: the person who has the responsibility of creating content for the m-learning application according to the indications of the chief writer; both professors and best students may be involved in this activity;
- analyst: analyses the requirements of the m-learning application;
- database designer: designs a database according to necessary data for the application;
- software designer: designs the architecture of the application;
- programmer: translates into code the design specifications;
- tester: verifies application behavior according to test cases;

- database administrator: manages the database server;
- server administrator: manages the web server;

Material resources are used by people to execute the tasks they have been assigned to. Material resources relevant to web based m-learning application development include:

- PC stations with office applications and internet access; they are used for writing documentation;
- development stations; computers with software development tools, used by analysts and programmers;
- development server; necessary to host the web application under development; after the application is completed it is further deployed to a production if server; the production server is not a resource as it is a deliverable of acquisition phase; if the production is external to the company/university then in acquisition a hosting plan is acquired; if it is internal to the university, then the device is bought also in acquisition phase;
- network devices: routers, access points, cables; if the application is meant to be accessed via the university network, then the classroom must be equipped with wireless access devices such as routers;
- printers, paper, cartridges; the elaboration of management documents, the reports of analysis and design phases, the didactic materials require printed versions;
- CD/DVD, external hdd or other storage devices; the work performed is kept electronically; backups are required for written code and database information;
- mobile devices for development; they are required to develop/test the application in a real environment; must not be confused with the devices from acquisition phase which are deliverables and will supply the classroom; the development devices are assigned to programmers; many features have to be tested on real devices as there are still many differences between real devices and emulators;

The resources that are not enough, are scheduled the manager having the role of assign-ing resources.

Costs that the project manager has to pay attention to are:

- software licenses; some software products have per computer license; in order to keep legal aspects of software development licenses must be acquired;
- hosting plans;
- service maintenance: devices are subject to failures;
- salaries; the amount of work a person does is multiplied with hourly wage; the amount of work for a person is obtained from the duration of the tasks that person has been assigned to;
- costs of materials; the manager inventories the necessary materials for the project and estimates costs;

Many cost categories are subject to restrictions. The manager has to pay attention to maximum or minimum thresholds imposed by law or by higher level management.

Risks must be taken into account for a successful project management. Risks are inventoried by the project manager. They are described, the probability of appearance is assessed and predefined actions to reduce the impact are established.

There are risks common with other types of projects and specific risks for the particular type of the project.

Common risks with software projects include:

- schedule risks; wrong estimations of task durations;
- budget risks; wrong estimations or unexpected cost overruns;
- operational risks; related to the implementation of working processes;
- technical risks; specific problems to software development.

Particular risks for software development of m-learning applications are:

- changing requirements; requirement stage is an early step in development; if changes to requirements occur when development is in late stages such as construction and testing, the induced modifications propagate through all stages causing additional work to be performed;

- incompatibilities between platforms is a major risk; it may occur inclusively when deploying the application from the development server to the production server;
- inconsistent rendering content; the same content is rendered differently on separate devices of different platforms;
- application is rejected by the users; accessibility and usability must play an important role in the design of the application.

6 Conclusions

M-learning web based applications have certain particularities among mobile and web applications. These particularities lead to specific project management approaches.
These peculiarities are found in:

- mobile technology as built-in;
- functionality of m-learning application;
- project management cycle;
- resources used;
- costs;
- risks;
- project team;
- software development.

Each m-learning web based project is unique. The project manager has to evaluate the situation and based on the proposed structure has to identify the needed elements to define the project accordingly in terms of objectives, tasks, resources, budgets, risks.

References

[1] G.R. Frederick and R. Lal, *Beginning Smartphone Web Development*. Apress Publishing, 2009, pp. 195-210

[2] European Air Traffic Management, *Best Practices for E-Learning Developers in ATM*. [Online]. Available: www.eurocontrol.int/humanfactors/gallery/content/public/docs/ DELIVERABLES/E_learning_Practices_ V1_Aug07_REP_HUM.pdf

[3] D. Brandon, *Project management for modern information systems*. Idea Group, 2006, pp. 130-133

[4] http://www.icteksolutions.com/company/ work-breakdown-structure.aspx

[5] P. Pocatilu, "Using cloud computing for E-learning systems," in *Proc. 8th WSEAS international conference on Data networks, communications, computers*, Baltimore MD USA, 2009, pp. 54-59

[6] M. Firtman, *Programming the Mobile Web*. Sebastopol: O'Reilly Media, 2010, pp. 45-50

[7] N. Mehta, *Mobile Web Development*. Birmingham: Packt Publishing, 2008, pp. 89-98

[8] T. Shelford and G. Remillard, *Real Web Project Management*. Addison-Wesley, 2003, pp. 22-39

Adrian VIŞOIU graduated the Bucharest Academy of Economic Studies, the Faculty of Cybernetics, Statistics and Economic Informatics. He has a master degree in Project Management. He holds a PhD in the field of Economic Informatics. He is an assistant lecturer in the Economic Informatics Department of the Bucharest Academy of Economic Studies. He published 16 articles alone or in collaboration and he is co-author of three books. His interests include: object oriented programming, data structures, multimedia programming, software quality management, software metrics refinement.