A teaching tool (ISM) for development and assessment of learning outcomes in the emerging area of infrastructure management

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Abstract: *Developing capabilities in management of civil infrastructure systems is an essential skill for a current Civil Engineering graduate. This new area of curriculum encourages students to appreciate the needs of the stakeholders and the community, objectives of sustainability as well as their prior technical knowledge on assessing performance of Engineering materials and systems. In developing the teaching program a challenge faced is the need for integrating a diverse range of activities and the knowledge base.*

The subject Infrastructure management developed at RMIT University is aimed at achieving the above objectives through incorporation of an industry based project as the major assessment task. Students select an infrastructure system for their major project and develop an asset hierarchy to divide the system in to assessable components. They then understand the deterioration mechanisms, failure modes, mechanisms and signs of distress to develop a condition rating method for the selected system. Finally, they develop a deterioration prediction method which is subsequently used to identify intervention level and to forecast maintenance cost, leading to an efficient Infrastructure Management Process.

To enable more effective assessment of the projects, a customised tool called Infrastructure Systems Manager was developed by the teaching team to capture the student input and the decision making process. The tool simulates the complete infrastructure management process and simulates the work place while allowing the educators to ascertain the students' understanding of the course content. The paper presents the process adopted in the development of the tool and the early outcomes.

Introduction

CIVE1173 Infrastructure management subject offered to final year students of the Bachelor of Engineering (Civil and Infrastructure) program at RMIT University was delivered on-campus for the first time in 2007. This is a new subject covering an area usually not covered by Civil Engineering Curricula. An infrastructure engineer operating in the current society essentially requires the ability to adopt a systems approach in managing infrastructure with an appreciation of the whole of life cycle of infrastructure systems covering the service (customer expectations), performance (technical and functional capabilities), and life expectancy. Core courses in the Civil and infrastructure engineering program has strengthened students' technical capabilities in design and construction of infrastructure systems whilst developing an awareness of sustainability and environmental issues. With this subject, students were expected to integrate their technical knowledge with the economic constraints, needs of the society and the environmental sustainability in developing a management plan for critical infrastructure systems essential for the service to community.

Learning program was compiled to facilitate skills development in identifying infrastructure systems and interdependencies, preparing an infrastructure management plan (IMP), identify methods in determining levels of service expected by stakeholders, developing a condition monitoring plan based on prior technical knowledge, evaluate risk of a given scenario and use an integrated approach in optimised decision making. Theoretical content was introduced through a team project of developing an infrastructure management plan for a selected infrastructure system. A decision has to be made at this stage whether a “problem based” approach or a “project based approach” is more appropriate. Perrenet et al (2000) gives a good comparison of the two approaches summarising that “project based” approach is directed towards application of knowledge whereas “problem based” approach fosters acquisition of knowledge through a project. In this particular course, significant content was introduced through formal lectures and industry presentations. However in some areas, students were expected to research and acquire knowledge through completion of parts of the project. Therefore the approach may be considered to be a combination of project and problem based modes with more emphasize on project based mode.

In developing team projects, initially attempts were made to develop sample projects closely simulating real life projects, which have sufficient diversity. However, some discussions with industry revealed that there are many projects which can be easily sourced from industry, which are real-life projects. A decision was then taken to use real life projects rather than simulated projects. A similar approach has been reported by Clausen (1998) where some of the projects in fact generated revenue for the school. Whilst this is not unusual, in delivering the course for the first time, many challenges were faced.

Learning Framework and Learning Program

Learning Framework

In order to relate the learning program to ‘real world’ infrastructure environment, it was important to recognise what the students would encounter when undertaking projects and ultimately have to deal with once they are in the workplace. The ‘International Infrastructure Management Manual’ prepared by the Association of Local Government Engineering New Zealand Inc and Institute of Public Works Engineering of Australia (2009) was identified as the accepted guide for those wishing to practice infrastructure or asset management around the world. It is a collective insight to all the specialities that are need to be brought together to be able ‘to do’ infrastructure management. Exposure to the multitude of influences that govern decisions around infrastructure is very important for students to understand before they finish their studies and enter the workforce. This subject starts to bring together all what they have learnt to date and makes them aware of the gaps in their knowledge, recognising the value of continuous learning and personal development once in the workforce.

Learning outcomes to develop graduate attributes of Engineers Australia

Learning outcomes can be mapped to four stage-one competencies of the Engineers Australia:

- Durability and design with civil materials – Knowledge of science and engineering fundamentals
- Understanding and evaluating infrastructure assets, Deterioration Mechanisms, Condition Monitoring on Site, Non Destructive Test Methods – Engineering ability, manage and document information
- Stakeholder analysis, performance measures, community needs – Professional and ethical responsibilities
- Analysis of data and development of predictive models – Engineering ability
- Decision making for optimised infrastructure management – Ability to utilise a systems approach
- Multi-criteria decision making – Understanding sustainability responsibilities and needs

In developing the learning program the elements of the Kolb model Figure 1 (Kolb, 1984) was considered and incorporated into the program design.

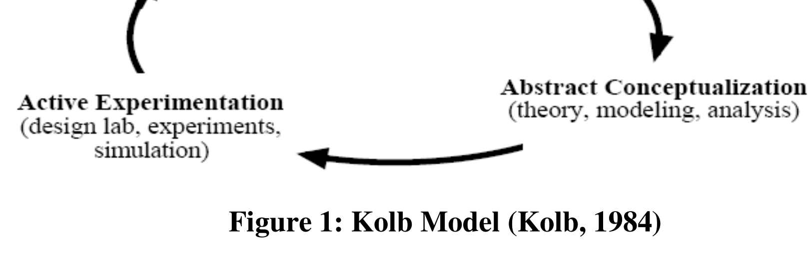


Figure 1: Kolb Model (Kolb, 1984)

All the abstract concepts have been combined with concrete experience since the material is introduced in the context of the project. These concepts include methods of measuring service, performance indicators, condition monitoring and non destructive testing, concepts of risk analysis, demographic models and demand forecasting, reliability and theory of probability. Reflective observation is encouraged through class room presentations by teams, and interim submissions. Active experimentation included non destructive testing labs and site visits. A list of projects was identified with the support of a number of industry personnel. These were selected to cover a range of infrastructure types so that through class room presentations students can appreciate the systems other than the one selected by their team.

Analysis of student performance

In analysing the students' performance during and after completion of the course, following observations were made:

1. The level of complexity of the projects had a significant variation making the assessment process quite difficult.
2. Industry interaction has been very limited and in some cases being limited to one meeting at the beginning of the project and one at the end.
3. Some organisations had well developed Infrastructure Management Processes (IMP)s which made students' job less challenging and it affected the learning. Plagiarism had to be carefully explained and monitored.
4. After completing interim submissions, most students did little work to integrate them in the final plan as an integrated document. Some plans appeared to be discontinuous segments covering project description, demand forecast, condition monitoring plan, risk analysis and optimised decision making model.
5. Whilst students demonstrated understanding of different elements of the learning program, understanding of the integration and inter-relationships were not clearly demonstrated. Especially elements where a problem based approach was expected, students didn't rise to the challenge.
6. Students were expected to develop an integrated decision making model covering, social, environmental and economic issues. This is one area; the lecturer used a problem based approach where students were expected to take a major responsibility for their own learning. Most students just did a comparison of several alternatives and presented it as an example.

Above observations led to the development of the teaching tool presented here which allows students to create their own management model as a working tool, eliminating the plagiarism issues of assessment and develop capabilities in integrating the diverse interdisciplinary content delivered in the learning program.

Tool Development

Edirisinghe et al. (2010) presents a holistic view of whole of life infrastructure management process. The Infrastructure Systems Manager (ISM) tool is designed to facilitate this infrastructure management process which composed of six stages. The ISM tool enabled the students to identify a particular infrastructure system, the elements and specify the data collection and condition rating methods for the components. ISM enables modelling the deterioration prediction and forecasting cost. Further, it facilitates management decision making based on the above data.

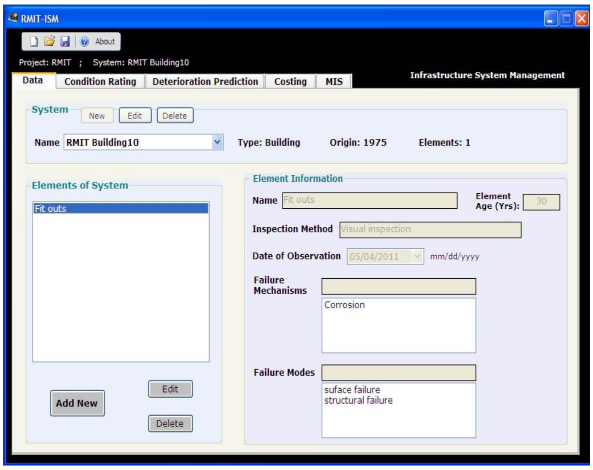
Tool Features

The key features of the ISM and corresponding modules to support these features are Data, Condition Rating, Deterioration Prediction, Costing and Management of Infrastructure System (MIS).

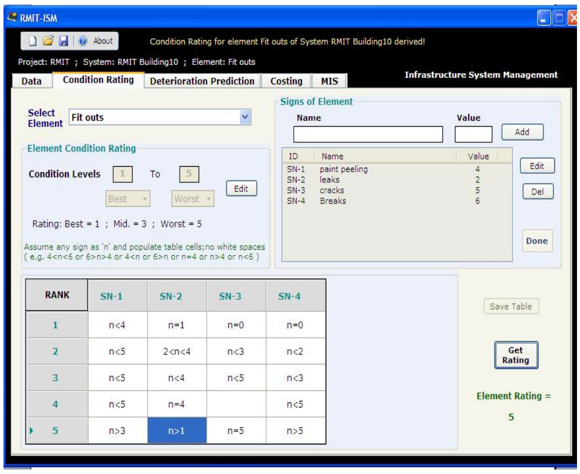
Data: The "Data" module of the tool is designed to facilitate the students to populate the required data for the infrastructure system including the attributes of the infrastructure system and the corresponding elements. This data is then stored in a database so that they can be retrieved when required. The tool supports multiple systems. Bridges, buildings, roads and waste water are some example systems. For a given system, students can analyse the whole system through component breakdown. The ISM "Data" module enables system data to be populated based on various elements the system. The element characteristics including various failure modes and failure mechanisms are also recorded in the system. Figure 2(a) illustrates the graphical user interface of the Data module of ISM tool.

Condition Rating: The ISM allows the students to populate condition rating method for each of the elements identified. Further, the students populate the signs of deterioration for each element. Consider a wastewater system for example; the Pipeline element has signs such as cracking, joint displacement, gas attack, debris/settlement and root penetration. Further, the students should define the condition rating method; for example 1-5 (1-best, 5-failed) for the overall element. Rule based knowledge repository that the students enter in to the tool is used to calculate the condition rating of a particular element. Figure 2(b) illustrates the user interface of the "Condition Rating" module.

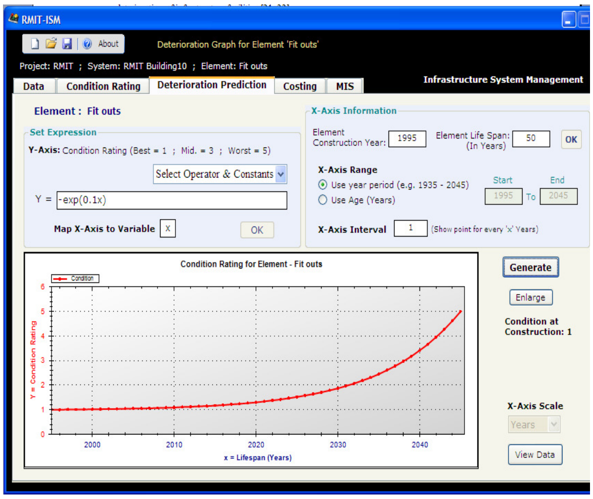
Deterioration Prediction: Regardless of the deterioration prediction method applied to the infrastructure facility, it is important to consider the influencing factors; hence the family of curves introduced by those factors and the sensitivity ranges of the influencing factors in addition to the main deterioration prediction curve needs to be studied and analysed. As Bamford, P. and Alisa (2008) note the influencing factors such as installed quality parameters (quality, design and execution), environmental parameters (indoor environment, and outdoor environment) and operation and maintenance parameters (conditions in use, maintenance regime) can be identified using ISO factorial approach. Based on the typical deterioration curve/pattern of the element the tool determines the deterioration for the lifespan of the element as shown in Figure 2(c).



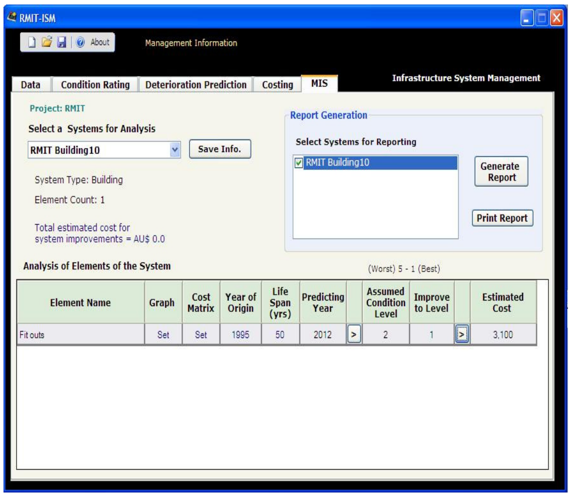
(a) The Data module



(b) The Condition Rating Module



(c) The Deterioration Prediction Module



(d) The MIS Model Module

Figure 2: Modules of ISM

Costing: Maintenance cost forecasting is an important element of infrastructure management (Edirisinghe et al., 2010). In forecasting maintenance costs, the first decision an asset owner has to make is the intervention levels and condition at which different categories of assets can be maintained within the budget. The ISM tool allows spanning and assessing the maintenance costs across the remaining life in order to prepare the maintenance budgeting over years. To facilitate cost forecast and decision making the students are required to analyse and enter the cost matrix, where there will be a cost associated with bringing the element condition to a better condition.

Management Information System (MIS): Once the cost model is available, various procurement and management decisions can be recommended by the system. The Figure 2(d) illustrates the MIS module of the ISM. The current version of ISM forecasts/predicts the costs based on the condition data and user inputs such as infrastructure ID under consideration and the age. In addition, the MIS module has the capability of generating reports related to the management decisions discussed above. Students submit a report generated by the system as their final submission.

Pilot Trials

The tool was trialled in semester 1 2011 for the first time. After few teething problems, the system worked quite well. Some specific issues identified by staff were:

- The need for a more diverse range of deterioration prediction data to populate the model
- Developing a data base of deterioration mechanisms and resultant signs which can be linked to development of the condition monitoring regime to cover the infrastructure systems selected by students.
- Incorporation of multi-criteria decision making in to the tool.

Student Feedback

Student feedbacks were sought as response to questions shown in Table 1. Student responses are summarised as below. There were 79 students enrolled and 28 completed class feedback surveys.

Table 1. Summary of Student Feedback

Questions	% agree	% undecided	% disagree
Each module of the tool focused on a specific topic area of the course	88.9	11.1	0
The tool helped me to understand the overall infrastructure management process	77.8	22.2	0
Modules of the tool assisted me to understand the relationship between different tasks in infrastructure management	77.8	22.2	0
Visual interface of the tool was satisfactory	88.9	0	11.1
Tool prompted me to reflect on the infrastructure management process	88.9	11.1	0
Tool assisted me to think about the input data needed for management of infrastructure	88.9	11.1	0
Tool was easy to learn and use	66.7	11.1	22.2
The layouts, language, user input and output used in the tool are consistent	55.6	44.4	0
Overall I am satisfied with the quality of the tool	77.8	11.1	11.1

Specific student comments included the following:

- The tool definitely helped with completing the report and explained a lot of things in greater detail. However some of the prompts didn't make much sense. It would be good if you could incorporate some of the details from the lecture notes into the help file with diagrams, for the deterioration models in particular. Otherwise, it's a very good application

- It would be a good idea if the tool featured tabs to insert mechanism or mode descriptions by the students, or even better if students could select these options i.e. "spalling, Delamination of concrete" and the tool included preset descriptions. Obviously, there will need to be a few tabs added which cover risk etc. But overall the tool was very useful to use with neat and understandable outputs.
- I believe the tool was overall a satisfactory way to progress through the management of an asset from signs of failure, deterioration and maintenance costs however I do believe that that overall flow of the tool could have been more user friendly. I did attend the tute for the tool, however few weeks on, I still found myself still unsure about the required inputs for certain sections (i.e. what it was asking of me, are the inputs actual or made up figures). Despite that, the use of the tool was quite straightforward.
- I think it is a good tool for learning and understanding how to go about a condition monitoring plan, however I question the deterioration prediction part of the ISM, and I don't see how this sort of deterioration prediction can be implemented in industry since a lot of data would be needed.

It is noted that the student comments indicated the issues that were also identified by the teaching staff. It is planned to address the help file and a database of deterioration mechanisms in the new version of the tool.

Conclusions

Challenges of delivering a work integrated projects in a final year Civil and Infrastructure Engineering subject: CIVE1173 Infrastructure Management has been presented. Some of the challenges included:

- Diverse range of project complexities, which created questions on equitability of assessment
- Some observed plagiarism from existing industrial systems
- Lack of development of capabilities in integrating the knowledge from interdisciplinary content
- Difficulty in obtaining data from industry on occasions

A new teaching tool has been developed to address these issues. The tool aimed to improve the assessment and capability development of students. First trial of the tool has resulted in reasonable acceptance from the student cohort and some evident improvement in efficiency and reliability of assessment. Analysis of the skills development through assessment has indicated adequate level of development of graduate attributes of Engineers Australia, discussed earlier. However, the ability of utilising a systems approach and corresponding assessment requires further careful planning.

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