

AN INNOVATIVE APPROACH TO INTEGRATE H&S ISSUES IN THE CONSTRUCTION PROJECT PLANNING USING SERIOUS GAME ENGINE TECHNOLOGIES

Rajiv Chavada, Ph.D. student

Centre for Construction Innovation Research (CCIR),

School of science and engineering, Teesside University, Middlesbrough TS1 3BA, UK

Email- R.Chavada@tees.ac.uk

Nashwan Dawood, Professor

Centre for Construction Innovation Research (CCIR),

School of science and engineering, Teesside University, Middlesbrough TS1 3BA, UK

Email- n.n.Dawood@tees.ac.uk

ABSTRACT

Efficient health and safety (H&S) planning is crucial if projects are to be delivered on time, on budget, and without experiencing accidents or injuries on construction sites. The H&S legislation has been introduced to eliminate hazards and co-ordinate H&S issues throughout the each stage of the construction projects. However, many employers face difficulty in converting the regulation directive into actions and practical implementation. The aim of this ongoing research paper is to illustrate key literatures in the area of H&S planning and advanced visualisation techniques in construction projects and identifies important research elements to demonstrate conceptual research framework. This will contribute towards successful development of an interactive decision support system that integrates H&S issues into 5D planning enabling safer, efficient and more productive construction sites.

The system prototype will focus on assessing the risks on construction sites occurs due to workspace conflicts and support infrastructures in order to avoid H&S issues in the construction projects. The system prototype will improve safety awareness on the construction sites and assist planner to review construction plan to be consistent with H&S. The research methodology of this research paper involves extensive literature review and to develop a knowledgebase module for H&S and workspace issues which will integrate into construction planning processes. Literature review revealed the requirement of an integrated interactive tool that can bridge the gap between H&S issues and advance visualisation techniques by exploiting Serious Game engine Technologies. There is a need for advanced visualisation IT tools which can be used to comprehend the construction operations and processes in order to avoid accidents/injuries before actual construction commences.

This research presents the research matrix (includes key research in H&S planning and advance visualisation techniques) and demonstrates research framework for the presented hypothesis. It defines the system process and functionalities. The system prototype will allow H&S to be managed as a part of the construction project planning and can improve H&S performance which is a key element for every construction project.

KEYWORDS

Integrated Health and Safety planning, serious game engine, advanced visualisation planning

1. INTRODUCTION

The Health and Safety (H&S) cost failures in the UK industry are estimated up to £6.5 billion per annum (HSE, 2009). The HSE statistics demonstrates that construction industry ranked second dangerous industry. Every year over 200 people died in accidents and over two million suffer illnesses caused by, or made worse by, their work. Embedded different H&S regulation into the construction planning is crucial if the projects are to be delivered on time and budget without experiencing any accidents or injuries. The key objectives of the construction projects are to provide an effective schedule, minimise cost, and comply with H&S regulations. These objectives are becoming difficult to achieve since the construction sites are very dynamic includes space requirements, H&S issues.

In this regard, the aim of the research paper is to investigate how H&S rules and regulations can be embedded into 5D modelling to enable safer, efficient and more productive construction sites. In order to deliver the aim, the number of objectives has been set:

- Investigate the research gaps, current theories and “State-of-the-art” techniques used in construction H&S planning and advanced visualisation of construction processes.
- Identify the important research components in order to develop a conceptual framework and prepared a knowledgebase database including Workspace, H&S risk assessment information.
- Implementation of an interactive decision support nD prototype to enable rehearsal of site construction processes, which uses several construction dimensions including safety, space, time and cost by exploiting Serious Game engine Technologies.
- Implementation of intelligent algorithm in order to identify the schedule, workspace and H&S conflicts in the construction sites based on empirical knowledge database to plan and control the construction processes.
- Run a case study to validate the model prototype through industrial experts.

The system prototype will identify conflicts in schedule, workspace and safety on the construction projects. This will assist planner/safety manager to review H&S issues in planning and provide an opportunity to amend it before the actual construction starts. The next section presents an extensive literature reviews related to H&S planning and advanced visualisation technologies in construction projects. It will be reviewed and classified in brief.

2. LITERATURE REVIEW

The number of literatures have been investigated related to H&S planning and advance visualisation technologies. This section mainly divided into two parts I) H&S planning and II) Advance visualisation technologies.

2.1 H&S planning

A number of research projects have been review related to H&S planning. It has been widely acknowledged that construction industry is the most dangerous industry among all. Chong Pui Ho et. al. (2000) discussed safety plan should work on important aspects such as hazard and risk. Therefore, it is always important to investigate possible H&S issues before commencing the work on sites. Approximate 5% of budget spends on H&S plan and procedures. However, many contractors argued that is it worth spending such amounts on safety plans? The proposed research identified that it is significant to assess hazards and risks on the site to be able to more productive and prevent accidents/injuries. The safety plan should review different constraint that includes the site factors, key constraints and effective plan. Rowlinson and Hadikusumo (2000) proposed IT tool as VR methodology Design-For-Safety-Process (DFSP) to simulate the safety hazards which inherited by construction objects and operations. It was an instruction based online guideline that accumulates the information from the research theories and H&S regulations. It has a mechanism for hazard identification, object picking, collision detection and possible hazard information from the accumulated knowledge. Carter and Smith (2001) strongly recommended that identify the hazards on the construction sites are the fundamental principal for any construction projects. Therefore, author argued that the projects have always a constraint related to time, cost and resource so operations need to be prioritising on the bases of risk assessment. Authors extended an approach to have a better understanding of safety hazards and risk measures associated with site operations by integrating the risk assessment into the research methodology. Three tier applications, Dynamic Data Driven (DDD) web prototype has developed to enter an accident report to the central database. It was helped to populate the possible accidents related operations and priorities task execution during construction phase. The prototype calculates the probability of hazard based on input historical data. It enables to achieve transparency for project planner and supervisor to identify possible H & S issues on sites. However, it can cause a problem because of poor data collection so it primarily depends on data collection.

Soltani and Fernando (2004) suggested that one way to make this industry a better working place is to implement effective H&S regulations during the planning of a construction project. The failure in planning appropriate support infrastructure affects safety, quality, and productivity adversely. To incorporate H&S into the construction project, several legislations have been introduced including CDM (Construction Design and management) 2007 to eliminate the hazards as the project progress. The primary goal of such legislations is to integrate H&S regulations to co-ordinates the H&S issues with the construction projects throughout the each stage of the construction process. Other literature indicated that the implementation of H&S regulation within the organisation will improve the project performance (Ciribini and Galimberti, 2005; Cameron and Hare, 2008). However, many employers found difficulty in converting the regulation directive into actions and practical implementation. Hare and Cameron (2008) discussed about implementing the regulations in the construction industries. The literature research supports that implementing such standards required a huge amount of documentation to satisfy H&S regulations. It results into very tedious process. Author has discussed about

current practices related to the H&S management systems during the planning stage to communicate H&S information with different stakeholders including client, designer, planner, H&S coordinator and sub-contractors. These tools will extract H&S information from paper documents; dig up H&S file data and present it into the effective way so the user can take the more precise detailed decisions on H&S matters. Author has classified some tools such as Responsibility chart and Risk register were identifying management of risk including H&S risks. Operation evaluation chart was developed to make design decisions. The Hazard ID tool was used for collaborative planning where different stakeholder can discuss how to identify and solve H&S problems. H&S milestones can plan the strategic level alignment into the programs. RAG (Red, amber and green) were prepared a checklist to sort the possible options of H&S risk. Kazi et. al. (2006) proposed a scenario based SIMCOM+ tool to investigate safety on the construction sites. It analyzed the structure information including temporary facilities, equipment, workers and materials in order to detect the collision among different entities on the construction sites.

Dolores et al. (2009) used questionnaire methodology to analyses the H&S regulation and requirements in construction industry and obtained the statistics. The authors determined that there are 10% lower accident rate in general after the H&S policies came into force. Hu et al. (2008) reviewed time-dependent structure theories during building construction. The authors argued that safety and structures analysis is not only dependent on static structures but also depend on other factors such as material behaviour and loading conditions, which kept change during building construction process. The authors have proposed an advanced digital framework of Building Information model (BIM) and 4D technology integrated with safety analysis method. This research provides an integrated solution of architectural design, structural calculation and construction management. It will help to achieve accuracy and efficiency of a complicated architectural design.

Kuan-Chen and Shih-Chung (2009) conferred that the construction processes are getting more complicated due to the large number of objects including structural elements and equipments in Virtual Construction. The authors proposed algorithm VC-COLLIDE identified conflicts on static or dynamic construction sites and determined distance between large dynamic 3D objects in virtual construction sites by different scenarios. The Open Dynamic engine (ODE) was used to rehearse the operations sequence efficiently and detect the collision status in the real-time virtual construction processes. Sacks et. al. (2009) proposed algorithm based methodology CHASTE (Construction Hazard Assessment with Spatial and Temporal Exposure) that calculates the probability of a potential victim during loss-of-control events.

In conclusion, failure of H&S planning affects the construction project economically as well as productively. There are existing tools in the industry but lack of advanced integrated system to communicate H&S planning of construction project. The proposed system will focus on assessing the risk on the construction sites occur due to workspace conflicts in order to avoid accidents/injuries on the construction sites. This will contribute towards successful development of an innovative methodology focusing on H&S awareness on the construction sites.

2.2 Advanced Visualisation Technologies

A number of technologies have been reviewed to identify the use of IT technologies for the advance visualisation planning. Li et al. (2003) described that the lack of innovative IT tool for the construction planner to assess and validate his planning can result into false operation planning, which will cause a lot of rework in the construction phase. Therefore, authors suggested that VR technology is the solution to the above problem. The authors developed knowledge base system called VCE (Virtual construction laboratory experiments), which enables the planner to examine virtual experiments of advance construction technologies, operation and process. Dawood et. al. (2005) proposed innovative advanced planning VIRCON (VIRtual CONstruction) tools in order to investigate sequential, spatial, process conflicts and temporal aspects of construction schedules before commencing the work on the site. It allowed planners to rectify and trade off the temporal sequencing of tasks with their spatial distribution to rehearse the project schedule.

Huang et al. (2007) argued that 4D-CAD system lack design and construction specific components such as scaffolding or other temporary facilities including storage area, carpentry shop, integrated with the system. Such 4D model also does not specify the space requirements of temporary infrastructures, which might result into space congestion, productivity loss and safety hazard. The author proposed a framework that allowed the project planner to check the safety, activity operation sequence, temporary infrastructures based on Dessault Systems solutions (DS). The system assisted to visualize 3D animation of a construction plan before actual start-up of a construction work and aid planners to analyses, simulate and model given prototype.

Zhou et al. (2009) proposed methodologies that support interactive, collaborative communication prototype. The proposed approach achieves the transparency by allowing an interactive and collaborative communication, to review construction plan and 4D-simulation model directly from 3D unique model. Author proposed distributed

environment 4D prototypes to rehearse the real time construction operation sequences and verified the model through industrial case studies. Effective user interaction and Computer Supported Collaboration Work (CSCW) were the important factor for the proposed novel approach. However, it has further research scope such as Building information modelling (BIM) adoption for more efficient Product breakdown structure (PBS) collection using the reliable conflict detection system. So it could produce a more robust and reliable construction plan. FORBAU is a virtual construction site project that focused on distinct infrastructure projects to improve planning and management of construction sites. One main objective was to rehearse the process flow from planning to execution phase (Borrmann et. al., 2009).

Kuan-Chen and Shih-Chung (2009) supported that the construction processes are getting more complicated due to the number of objects including structural elements and equipments in Virtual construction. The proposed algorithm VC-COLLIDE to identify conflicts on static or dynamic construction sites and determined distance between large dynamic 3D objects in virtual construction sites by different scenarios. This algorithm would rehearse the operation sequence efficiently to detect the collision status in the real-time virtual construction processes. To determine collision and different scenarios, an algorithm will identify the geometrical object shapes such as cylindrical, spherical, etc.

Conducting a real time experiment on the construction operation sequences are expensive and hazardous, the construction industry is looking for an alternative approach to rehearse different construction operations to sustain effective project planning and safety control. Although many digital technologies have developed to visualise the innovative construction design, some virtual prototypes were developed to enhance effective communication of design, integrated planning and visualisation of the construction processes. The MineVR (Virtual Reality Safety Model, 2000) is Virtual Reality (VR) based simulation model of reconstructing a mining accident simulation, which have successfully used to educate people in preventing H&S hazards. Santa Clara University Library (NMC Virtual worlds, 2008) built in "Second Life" (SL) in the early phases of the construction to explore innovative ideas for interior spaces. The virtual construction site is used to visualize dynamic navigation of the construction site however, the rich interactivity function of VR is not used (Li, H. et. al., 2003) effectively. The VR's ability to visualize dynamic operation sequence enables the construction planners to identify any possible H&S problems of the site layout before actual construction begins (Boussabaine, A.H. et. al, 1997). It can demonstrate different "What-If" scenarios with limited resources and efforts. The visualisation and control of the construction site operations will become prominent in the next generation 4D/5D tools. Serious Game Technologies is an innovative approach of presenting the construction planning to the professionals and users with less-knowledge (Sawyer and Smith, 2008). Pui Ho et. al., 2000, Carter and Smith, 2001 and Cameron and Hare, 2008 concluded that there is still a lack of an advanced integrated safety approach in planning and visualisation to rehearse real time construction scenarios.

This research will develop novel methodology that integrates H&S issues with construction project planning using Serious Game engine Technologies such as XNA game engine coupled with object-oriented technology such as C# (.NET environment), to develop an integrated interactive tool for the construction professionals such as site supervisor/safety manage/planner. It will assist them to visualise, analyse and evaluate the construction process at the detailed level to improve their decision-making process (Waly, A. F. and Thabet, W. Y. 2003). The proposed system will identify conflicts in schedule, workspace and safety on the construction projects. This will give an opportunity to amend it before the actual construction starts. The outcome of this research will be an application of Serious Game engine tool used by the construction planners, designers and safety managers to improve H&S on the construction sites.

2.3 Research Matrix

The Research matrix builds up a grid to identify gaps and review the scope for improvement. It reviews previous key researches in H&S and Advance visualisation planning. It classifies the planning, visualisation, database and the research constraints including physical, workspace, policy, resource and contract (See Table 1 for Matrix of key research in H&S planning and Advance visualisation system).

The Research matrix demonstrates technological dependencies and time constraints are the important factors to be considered in all projects. The Research matrix has been carried out to deduce how the H&S issues can be embedded into construction planning. The research has a scope of improvement for integrating H&S issues on serious game engine technologies. There are also some other constraints such as people, space, safety policy and environment taken into consideration. However, very few researches support all specified constraints. In regards to workspace constraints, many researchers have considered different variables such as resource, H&S, schedule and workspace area. However, there is only one research that considers most of the type variables.

Table 1: Matrix of key research in H&S planning and Advance visualisation system

Constraint, database, visualisation, optimisation and planning techniques	Fischer et. al. (1999)	Rowlinson and Hadikusumo (2000)	Cartert and Smith (2001)	Waly and Thabet (2002)	Sriprasert and Dawood (2002)	Li et. al. (2003)	Elbeltagi et. al. (2004)	Soltani and Fernando (2004)	Dawood and Benjaoran(2005)	Ciribini and Galimberti (2005)	Mallasi and Dawood (2006) ; Mallasi (2009)	Kazi et.al. (2006)	Jang et. al. (2006)	Liapi and Paschoudi (2007)	Hang et.al. (2007)	Cameron and Hare (2008)	Sacks et. al (2009)	Lai and kang (2009)	Zhou et. al. (2009)	Benjaoran and Bhokha (2009)
Constraint																				
Physical Constraint																				
People		X		X				X	X	X		X				X	X			
Space			X	X	X		X	X	X	X	X	X	X		X		X	X		X
Environment									X								X			
Technological dependencies	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Policy																				
Safety policy		X	X				X	X	X	X		X			X	X				X
Workspace																				
Resource					X			X		X	X	X	X				X			
H&S issues							X	X	X	X		X			X		X			X
Schedule					X		X				X						X			X
Work-area							X		X		X	X	X		X		X			
Contract																				
Time	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Cost	X													X						
Construction planning																				
Planning and scheduling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Monitoring and Controlling					X					X										X
“What-If” modelling	X					X		X			X	X						X		
Algorithms																				
Numerical algorithms	X							X		X		X		X	X		X	X	X	
AI and Knowledgebase algorithms					X		X		X		X		X							X
Database		X	X	X	X						X	X		X						X
Visualisation																				
2D/3D view								X												
4D model					X		X		X	X	X	X	X		X		X	X	X	X
Web Interface		X	X		X															
VR model		X		X	X	X					X	X			X			X		

Modern construction planning techniques required more than just planning and scheduling. It requires an interactive planning that combines the planning, execution and control of a construction project and provides iterative feedback to improve the construction plan. There are different types of algorithm such as computational, artificial intelligence (AI) and knowledgebase algorithms, which can incorporate into system prototype in order to put some constraint. In terms of defining the construction site rules, knowledgebase algorithm can be very useful. In the other end, there are various visualisation techniques from 2D to nD/VR modelling to assist construction professionals to demonstrate and manage construction site processes. In conclusion, these constraints such as physical and logical should be coordinated in order to produce safer, efficient and productive

system by exploiting Serious Game engine Technologies. The next section 3 describes about development of system framework. It discusses about the main research components.

3. DEVELOPMENT OF THE SYSTEM FRAMEWORK AND FUNCTIONALITIES

The aim of this section is to introduce a conceptual system framework for this research. It demonstrates the framework of the proposed system and presents the important components of this research.

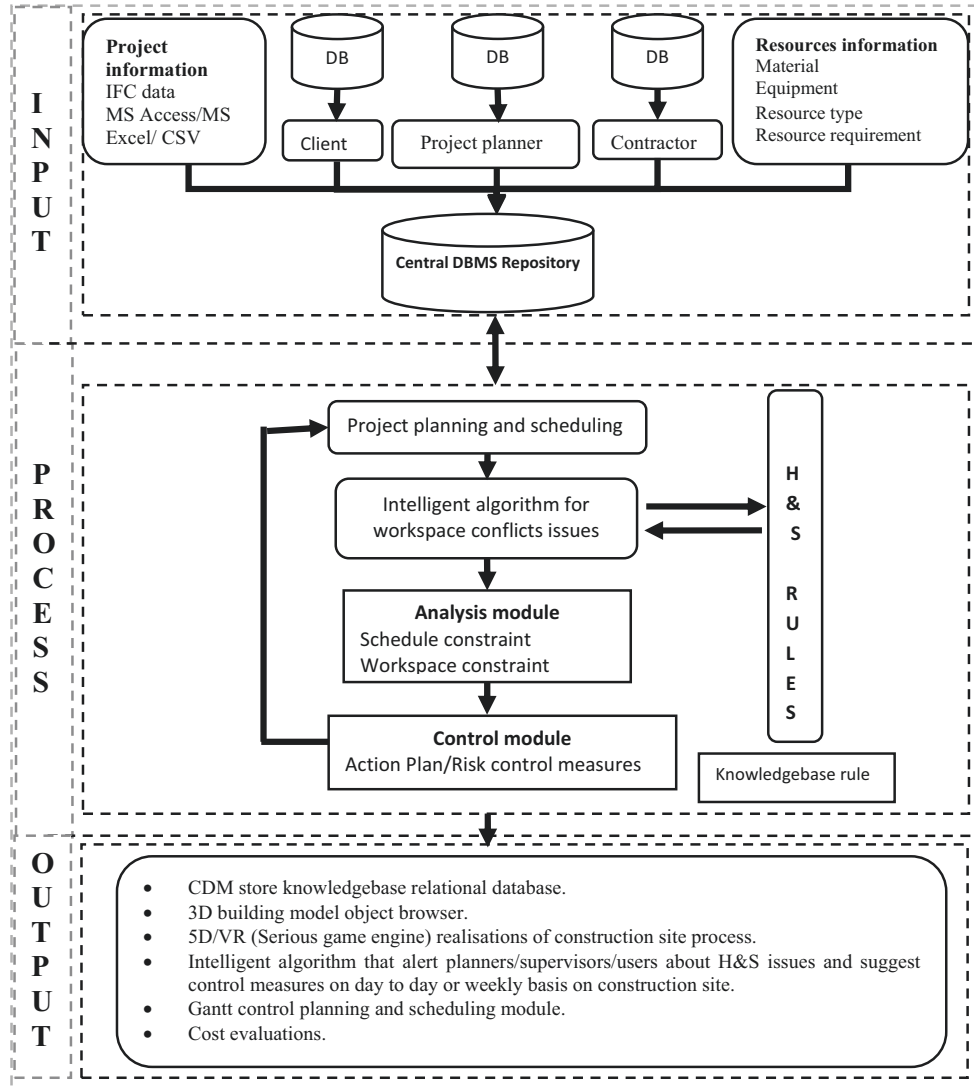


Figure 1: System Framework

The figure 1 illustrates the overview of the proposed system framework. This framework divides into three phases including Input (Data structure), Process (Integrated core system module) and Output (Final outcomes). The system process defines the business logic in order to make intelligent planning by identifying schedule, workspace and safety conflicts. The intelligent algorithm will communicate with Knowledgebase module to specify the site rules related to H&S, workspace or resources. The knowledgebase module stores the risk assessment information and workspace classification details to allocate workspace type. The analysis module will define the constraint in order to check schedule and workspace conflicts. If the intelligent algorithm finds any conflicts, the control module will propose an action plan or Risk control measures in order to resolute the identified conflicts. The control module will suggest the possible solutions to improve the existing planning and provide iterative feedback to users to improve planning decision based on knowledgebase module.

3.1 Input (Data structure)

An input data layer stores the detail information of project planning and design, users and resources into the database. All data input will store into the DB Repository. DB Repository will establish the communication of database with the integrated software prototype.

- **User's data information**- It stores user database information to plan construction project collaboratively. It allows interacting different stakeholders including owners, contractors, planner and project designer to improve the better decision-making process at different phases of the construction project including designing, planning and controlling.
- **Resource information** – It stores the resource information into the database. Various resources will have different characteristic and type.
 - Materials, Workers, Equipments.
- **Project information**- It presents a file information into one of the following formats : IFC Data/ MS Project/MS Access/ MS Excel/ SQL/Text/CSV
- **Central Repository DB**- It has input from various databases and unified into the central database. It will establish db connection with core model.

3.2 Process (Integrated core system modules)

A knowledgebase core layer creates business logic for an integrated system.

Integrated system logic - It iterates the interaction between the intelligent algorithm, knowledgebase module (H&S issues), analysis module and control module. It will provide recursive feedback to improve the future plan and schedule of the construction project.

- **Intelligent algorithm** – It analyses the different constraints including schedule, workspace and safety.
 - **Schedule constraint**- It defines the criteria for different activity to prevent the conflicts.
 - **Workspace constraint**- It classifies the workspace type and the causes of conflict in a specified workspace. Workspace types include installation space, transfer space, safety space, fabrication space and loading space (Moon et al., 2009). Conflicts in installation space occur due to over allocated resources or a lack of installation space area. Conflicts in transfer space occur because of transferring the equipment and materials in restricted work space. Fabrication space conflict occurs when another workspace moves towards the fabrication space. Conflict occurs in safety space due to accidents or injuries happened by falling objects. Conflicts occur in loading space due to fall or collision while moving the equipment or materials. The main causes of workspace conflicts are materials, equipment, workers and workspace itself.
- **Knowledgebase Module**- It integrates the knowledgebase H&S rules into the workspace conflicts algorithm. It defines a procedure based on set of rules to check the problems and proposes a solution. The defined procedure is carrying out by some steps i) Identify the conflicts, ii) Check the type of conflicts iii) Determine the cause of conflict iv) Suggest different solutions for indicated problem v) Propose a final solution. It also stores information related to Risk assessment of different activities. It will create a Risk template where user can configure risk information related to activities.

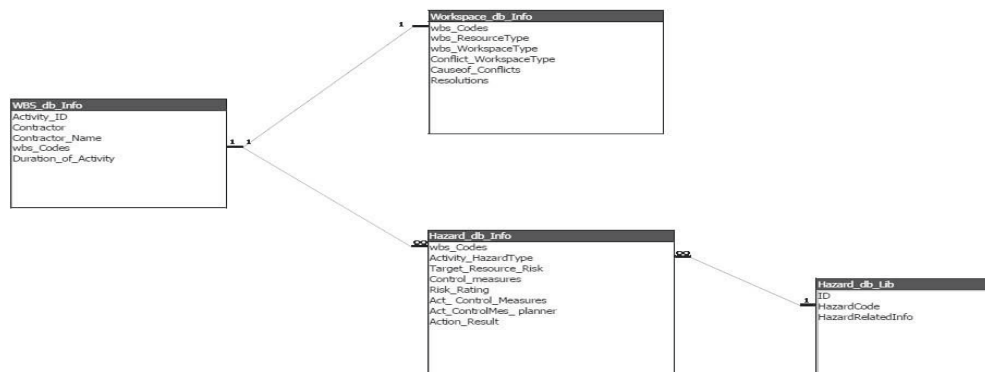


Figure 2 : Data structure of Knowledgebase module

The above figure illustrates the data structures of the CDM store database. This database incorporates knowledge of the H&S issues, workspace and resource types.

- **Control module** –It will constraint the decision variables (equipment, material, workers and workspace) to propose safety and congestion free solutions by innovative interactive planning technique that provides the workable backlog to improve the project plan. It will suggest guideline of different control risk measures on day to day or weekly basis on construction site.

3.3 Output (Final Outcomes)

It is an interactive layer which presents the expected final outcomes of the model prototype (See figure 2). User can rehearse different scenarios of a real time construction process as “What-If” and interact with the software prototype to explore the project experience with several dimensions including safety, space, time and cost.

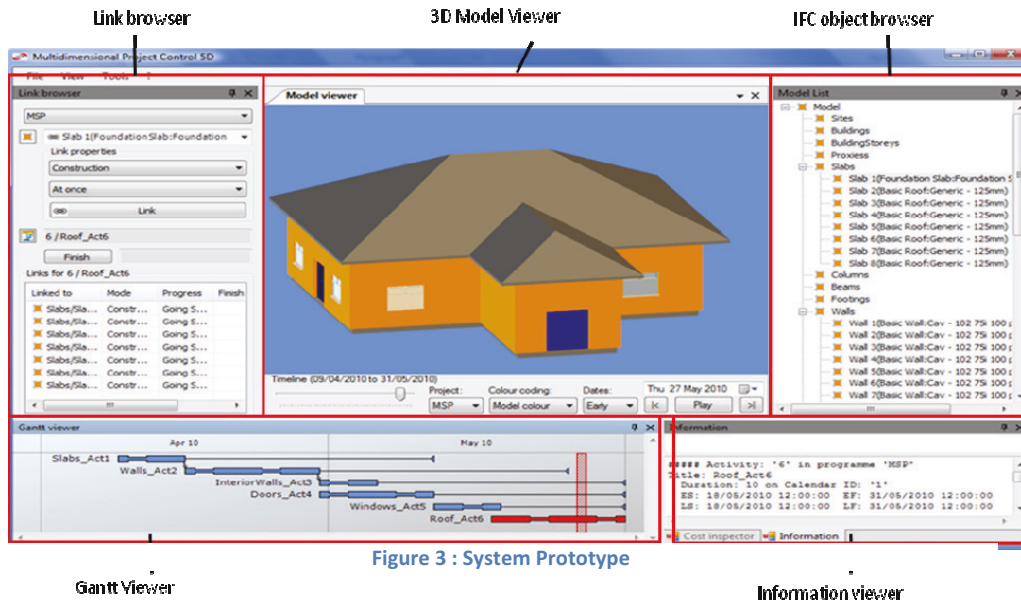


Figure 3 : System Prototype

- nD prototype – the outcome of the system prototype will be as following:
 - 3D model + safety, space, time and cost visualisation.
 - Planning and scheduling module.
 - Configuration module I) Workspace allocation II) Risk assessment
 - Cost evaluation.
 - Rehearse different “What-If” scenarios of real-time process in the game engine environment.

This framework demonstrates the outline of the system prototype. It assists to create data structure for this prototype and develop an intelligent algorithm to satisfy the objective. This framework proposes a conceptual framework to develop an innovative interactive reviewer tool to bridge a gap between construction H&S issues, construction planning and advance visualization techniques by exploiting Serious Game engine Technology.

3.4 System Functionalities

The system will carry out following functionalities.

- CDM Storage database – It develops a Relational-database system to formalise the structured activity data information and associated risk with it. It also specifies the workspace classification and allocation information.
- Develop 4D (3D + Schedule) model by assembling building objects to rehearse the construction site progress in a game engine environment.
- Create a Risk assessment template where user can input Risk related information to each activity and incorporate the risk information into activity planning.
- Create a Workspace template where user can input Workspace related information to each 3D object into model viewer.
- Analysis module- integrates an intelligent algorithm to identify the risk level of the construction sites. Add Metadata information to the activity planning.
 - Schedule, workspace and safety constraints.
- Assess the probability of risk in workspace area on construction sites (only identified hazards can be planned for H&S control measures).

- Assess Risk information using Custom templates related to each activity.
- Derive Risk-level Grid in order to assess the criticality of workspace area.
- Define activity codes- To measure the severity of accidents/injuries on site.
 - High, Medium, Low (It changes as the project progress).
- Resolution module: - H&S Control measures.
 - The system will suggest the possible solutions to improve the existing strategy and provide iterative feedback to users to take decision based on knowledgebase module.
 - Resolute the workspace conflicts and congestion issues by optimising workspace or resources.
- Report Module: - Prepare H&S file to comply CDM regulations.
 - H&S report that includes identified and existing H&S issues.
 - H&S report also address action plan to prevent H&S issues on sites. It also Keep the track of progress data.

The development of the Serious Game engine tool will contribute towards increasing an awareness of the H&S issues on construction sites for construction planner/Safety manager/project coordinator to manage the consistent H&S planning. Therefore, the users can be more confident when using 5D visualisation for communicating the construction project plans.

4. CONCLUSION

Co-ordination of H&S issues throughout the construction planning at each stage of the project is mandatory requirements for construction project. In this paper, the research matrix has been prepared to identify the research scope and gaps by investigating the several key researches. It is concluded from review that there is a need of integrated solution that can bridge the gap between construction site H&S issues and advance visualisation techniques. It needs to move forwards towards the integrated module based knowledge management system where H&S, support infrastructures and workspace information can be integrated. The system needs to support advance visualisation techniques for users with less knowledge such as Serious Game engine Technologies.

In order to add value to the existing practices and researches, need an integrated knowledge management algorithm that incorporates H&S, workspace and support infrastructure information. The system will focus on assessing the risk on construction sites occurs due to workspace conflicts and support infrastructures in order to avoid accidents/injuries. The research proposes a conceptual framework assists to develop an innovative interactive system to bridge a gap between construction H&S issues, construction planning and advance visualization techniques by exploiting Serious Game engine Technology. This will contribute towards successful development of an innovative methodology focusing on safety awareness on the construction sites and assist planner to review the construction plans and amend it before the construction work commence.

5. FUTURE WORKS

The development of the intelligent algorithms to configuration, classification and allocation of site workspaces. It will check the schedule, workspace and safety conflicts to plan monitor and control the construction projects. The system will develop a resolution strategy in order to resolve the identified conflicts using optimisation algorithm such as Genetic algorithm and prepare an action plan or control risk measures to manage the construction sites. The system will validate and verify through the real time case-studies.

REFERENCES

- Benjaoran, V. and Bhokha, S (2009) - "An integrated safety management with construction management using 4D CAD model", Safety science
- Cameron, I. and Hare, B.(2008)- "Planning tools for integrating health and safety in construction", Construction Management & Economics, Vol. 26 Issue 9, Pages 899-909
- Carter G and Smith S (2001)-" IT tool for construction site safety management", IT in construction in Africa 2001; Mpumalunga,30 May-1 June, South Africa:[Available on]: <http://itc.scix.net/cgi-bin/works/Show?w78-2001-55>
- Chong Pui Ho, D., Ahmed, S. M., Chu Kwan, Jack and Wei Ming, F. Y. (2000) -"Site Safety Management in Hong Kong", J. Mgmt. in Engrg. Pages 16-34,DOI:10.1061/(ASCE)0742-597X(2000)16:6(34)

- Ciribini, A. and Galimberti, G. (2005) – “4D Project Planning and H&S Management”, [Online Available at]: <http://itc.scix.net/cgi-bin/works/Show?w78-2005-d3-3-ciribini>
- Dawood N, Scott D, Sriprasert E and Mallasi Z (2005)- “The virtual construction site (VIRCON) tools: An industrial evaluation”, *ITcon Vol. 10, Special Issue From 3D to nD modelling*, pg. 43-54
- Elbeltagi, E., Hegazy, T. and Eldosouky, A. (2004) - “Dynamic Layout of Construction Temporary Facilities Considering Safety”, *J. Constr. Engrg. And Mgmt. Volume 130, Issue 4*, pp. 534-541
- Fischer M, Aalami F, Kuhne C, Ripberger A. (1999)- Cost-loaded production model for planning and control, Lacasse M A, Vanier D J, *Information technology in construction*, volume 4, ISBN 0-660-17743-9; Vancouver, May 30 - June 3, Canada <http://itc.scix.net/cgi-bin/works/Show?w78-1999-2813>
- Health and Safety Executive's 'Ready Reckoner', (2009)- [Online Available at]: http://www.hse.gov.uk/costs/costs_overview/costs_overview.asp [Accessed on 11/10/2009]
- Hu, Z., Zhang, J. and Deng, Z., (2008) – “Construction Process Simulation and Safety Analysis Based on Building Information Model and 4D Technology”, *Tsinghua Science & Technology*, Volume 13, Pages 266-272
- Huang, T., Kong, C.W., Guo, H.L., Baldwin, A. And Li, H. (2007), “ A virtual prototyping system for simulating construction processes “ , *Automation in Construction*, Volume 16, Issue 5, Pages 576-585
- Hyoun-Seung , J. (2004) – “Genetic algorithm for construction space management”, *KSCE Journal of Civil Engineering-Korea*, Pages 365-369
- Jang, H., Lee, S. and Choi, S., (2007) -“ Optimization of floor-level construction material layout using Genetic Algorithms” *Automation in Construction* Volume 16, Issue 4, Pages 531-545
- Kuan-Chen, L. and Shih-Chung, K. (2009)- “Collision detection strategies for virtual construction simulation”, *Automation in Construction*, Volume 18, Issue 6, October 2009, Pages 724-736
- Li, H., Ma, Z., Shen, Q. and Kong, S., (2003) - “Virtual experiment of innovative construction operations “ , *Automation in Construction* Volume 12, Issue 5, Pages 561-575
- Moon, H. , Kang, L., Dawood, N. and Ji, S. (2009) - “Configuration method of health and safety rule for improving productivity in construction space by multi-dimension CAD system”, *ICCEM/ICCPM*, Jinju Korea
- Naji, Khalid K. (2006) - “New Trends in Construction Site Safety and Management Based on Virtual Environments”, [Available on]: <http://itc.scix.net/cgi-bin/works/Show?6585>
- NMC Virtual World (2008)-[Online Available at]: <http://virtualworlds.nme.org/portfolio/santa-clara> [Accessed on 10 Mar. 09]
- Rowlinson S and Hadikusumo B H (2000) – “Virtually real construction components and processes for design-for-safety-process (DFSP)”, *Construction Information Technology 2000, Taking the construction industry into the 21st century.*; ISBN 9979-9174-3-1; Reykjavik, Iceland
- Sacks, R., Rozenfeld, O. and Rosenfeld, Y. (2009) - “Spatial and Temporal Exposure to Safety Hazards in Construction”, *J. Constr. Engrg. and Mgmt. Volume 135, Issue 8*, pp. 726-736
- Sawyer, B. and Smith, P. (2008) – “Serious game taxonomy”, [Available at] <http://www.seriousgames.org/>, [Accessed on 06 Dec. 09]
- Soltani, A. and Fernando, T. (2004) -“A fuzzy based multi-objective path planning of construction sites “ , *Automation in Construction* Volume 13, Issue 6, Pages 717-734.
- Virtual Reality Safety, (2000) – [Online] Available at http://www.mishc.uq.edu.au/Research/Virtual_reality.pdf [Accessed on 16 Mar. 09]
- Waly, A. F. and Thabet, W. Y. (2003) – “A Virtual Construction Environment for preconstruction planning “*Automation* Volume 12, Issue 2, March 2003, Pages 139-154