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Adaptive Design and Its Need

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Abstract— Design now a day are not only dependent on the technical soundness, quality requirements but it also requires to comply with environmental protection provisions, contractual requirements, provisions for experience by design which considers the human factor etc. Design need to performed quickly and need to be adaptive with the changing conditions at the place of construction. Soil risk and system risks need to be evaluated and impact need to be assessed for appropriate treatment of risk. Terminologies as specified in the codes or design specification should have clear, shared understanding with regard to the meaning of the terminology. In order to achieve above there is a need to adopt the advances in information technology like semantic web technologies which enable collaboration between different entities of system so that it helps realise the vision 2025 of civil engineers. Changes at site and its impact can be assessed so that preventive actions can be taken in order to avoid accidents. In this paper the need for the concept adaptive design is discussed and term adaptive design is defined.

Keywords— OWL, RDF, SWRL, SPARQL, ONTOLOGY

I. Introduction

Vision 2025[1] for civil engineers is spelt out in five requirements to enhance the global quality of life. In order to achieve the vision there is need to adopt the latest advances in information technology and advancements in technical domain.

Semantic web technologies like owl, RDF, sparql, swrl etc enables to establish a better communication between the humans and software agents in a meaningful manner. Usage of these technologies helps to achieve the collaboration between the entities of the system.

As per the survey[2] conducted on the risks with regard to infrastructure development in India, collaboration and communication between different entities is cited to be one of reason, which in turn results in delay in approvals, land acquisition etc. Delays will have an effect on choice of design alternatives.

Accidents like Nichol highway, Singapore are attributed to improper estimation of design parameters [3] and to misinterpretation of provisions in code with regard to stiff bearing length and omission of splays. Thus design error is the one of the cause for Nicoll highway collapse [12]. Adaptive design takes into account theories which provide better estimates on stresses and strains. For example usage of Terzaghi's Mohr- Coloumb equation for applied soil mechanics can be replaced by critical state soil mechanics [4] .

Ontology provide shared vocabularies or by explicitly modelling vocabulary differences, context, and meaning. The application developed based on ontology helps minimize misinterpretation of provisions of code such that Nicoll highway accidents can be avoided in future. Infrastructure development needs to be maximally efficient, flexible and reliably produce high quality infrastructure without extensive regulatory oversight. In order to achieve the above, designs need to change with the changing requirements; also there is a need to change in design if there is a non compliance to the regulatory requirements. Hence there is a need for adaptive design.

Another roadblock as per the survey [2] conducted on the risks with regard to infrastructure development in India is non compliance to contractual provisions. Project managers may not be able to remember all contractual provisions and apply them to the context. Usage of semantic web technologies will help in compliance of certain activity with regard to contractual provisions. If there is a deviation then design needs to be adaptive.

Yet another important aspect in the decision making with regard to the infrastructure projects are risk evaluation. There could be the case where the conditions at the place of construction differ drastically with that of the assumed conditions during initial design.

Risks are evaluated by taking systems approach and by using the techniques like FMEA. Ontologies can be developed which captures the domain knowledge and develop applications which gives the risks by taking into account entire system and soil risk.

Experience design is a practice of designing products, processes, services and environments with a focus on the user experience. Meaningful user experiences designs are enabled by the usage of semantic web technologies.

Taking into account the above aspects, a flexible design approach i.e. adaptive design is defined in which risk based approach is considered for changing needs /requirements at site so that accidents can be prevented, compliance to contractual provisions can be enforced and experience design is enabled.

II. Basic definitions

A. Ontology

Ontology is a conceptual data model used to link together other, more granular data models in order to reach agreement on data meanings-either by committing to shared vocabularies or by explicitly modelling vocabulary differences, context, and meaning. [10]

Ontology can also be defined as a model of any bounded region of interest expressed as concepts, relationships, and rules about constructs and associations of interest to a modeller. [10]

B. Semantic Web

The semantic web is an extension of the current web in which information is given a well defined meaning, better enabling computers and people to work in cooperation. [10]

C. Knowledge Management

Holm, Olla, Moura and Warhaut (2006) defined the general objective of knowledge management as “getting the right information on to right people at the right time” such that the information can be used more effectively. [10]

III. Need for adaptive design

A. Vision 2025

The vision of 2025[1] for civil engineering is given as follows

Entrusted by society to create a sustainable world and enhance the global quality of life, civil engineers serve competently, collaboratively, and ethically as master:

- Planners, designers, constructors, and operators of society’s economic and social engine -- the built environment;
- Stewards of the natural environment and its resources;
- Innovators and integrators of ideas and technology across the public, private, and academic sectors;
- Managers of risk and uncertainty caused by natural events, accidents, and other threats; and
- Leaders in discussions and decisions shaping public environmental and infrastructure policy.

In order to achieve the above vision, collaboration between different entities of system can be made possible between humans and software agents by using semantic web technologies like owl, rdf, sparql, etc. Enforcement of quality provisions can be made possible using the above mentioned technologies. Adaptive design uses semantic web technologies so as to enable collaboration.

B. DESIRED STATE OF INFRASTRUCTURE DEVELOPMENT INDUSTRY

The desired state for the infrastructure industry can be in lines of that of pharmaceutical manufacturing industry which is aptly put forth by Dr Janet Wood Cock [5]. “A maximally efficient, agile flexible, pharmaceutical manufacturing sector that reliably produces high quality drug products without extensive regulatory oversight”

In the similar lines for infrastructure development industry can have a desired state as “A maximally efficient, agile, flexible, infrastructure development sector that reliably produces high quality infrastructure without extensive regulatory oversight.” For being agile and produce high quality infrastructure one need to have automated mechanisms which check for compliance of provisions as given in quality management systems or energy management systems and in order to be agile, changes need to be incorporated as and when required. As the requirements change the design also need to be done in an adaptive manner. Hence there is a need for adaptive design.

C. PROBLEMS

1) Accidents:

Nicoll highway collapse is attributed to misinterpretation of codal provisions with regard to stiff bearing length and omission of splays. Thus design error is the one of the cause for Nicoll highway collapse. [12]

Had the engineers at site were provided with an application which provides with correct interpretation of provisions of code and if it enables implementation of provisions of code then Nicoll highway accident could have been avoided.

Ontology provide shared vocabularies or by explicitly modelling vocabulary differences, context, and meaning. The application developed based on ontology helps minimize misinterpretation of provisions of code.

The original analysis of soil-structure interaction was carried out using nonlinear finite element methods with linearly-elastic, Mohr-Coulomb (MC) models to represent the soil behaviour. The use of this soil model together with drained effective stress strength parameters (c' , ϕ'), in an undrained setting, greatly overestimated the undrained shear strength of the Marine Clay in the original design leading to a serious underestimation of computed wall deflections, bending moments and the mobilization of forces in the JGP pile-rafts. [3]

Had the observation that the change in the drainage condition is given as an input parameter in the adaptive design application, it would have given correct estimate. Here there is a need to take into account better design approach for better estimate. For example usage of Terzaghi's Mohr- Coloumb equation for applied soil mechanics can be replaced by critical state soil mechanics. [4]

2) Compliance to existing provisions:

Non compliance of the existing provisions in technical, contractual, quality management and energy management systems can be detected with application developed using owl,rdf and sparql etc.If there is non compliance then its effect on the design is evaluated in an adaptive manner.

Technical Code Provisions:

With the help of the semantic web applications and global position system (GPS) enabled total stations can provide impact of the levels taken on the field in relation to the code provisions. For example if the code provisions state that the tolerance limit is say 5 mm with respect to the design levels, the semantic web applications compares with the design and actual levels and if there is a deviation in the levels then its impact not only on the technical aspect of the design but also on the schedule, cost can be arrived at the moment the levels are recorded on the field. It enables transparency and enforcement of code provisions.

Contractual Provisions:

The project manager may not remember all the contractual provisions , the semantic web applications provides the impact of any unforeseen event on the contractual provisions in contract and it enables availability of the impact of event on the project. For example there is steep price hike in the diesel, its impact on the project with relation to parameters such as cost, quality etc and semantic web applications provide with alternative design approaches in an adaptive manner.

Quality and energy management system provisions:

Similarly the design requirements may change due to improper construction in the field. The impact on design by keeping quality and energy management system provisions constant can be known and can be made available to the context.

D. CHANGES

1) Insitu conditions differ with assumed conditions:

The unanticipated field conditions could be

- Uplift pressures
- Non availability of construction components (For example channel sections used for construction are available of size different from that of specified size of design specification).
- Unforeseen events (For example an office is located nearby a highway and due to un anticipated rush in traffic, office bearers proceeds with laying a speed breaker which is in violation of highway specification(legal or technical))

In all the above cases what could be effect on the structure that is constructed need to be evaluated. The evaluation need to take into account different views into the consideration. For example what are the technical implications (design of Structural point view, geotechnical point of view), Legal point of view, compliance to contractual provisions, compliance to code provisions, compliance to environmental provisions etc

2) Changes In Existing Provisions

There can be changes in the codal provisions, contractual, quality and energy management provisions while the project is being executed, its impact on design can be evaluated adaptively.

E. MEANINGFUL EXPERIENCE DESIGN

Experience design is a practice of designing products, processes, services and environments with a focus on the user experience [6]

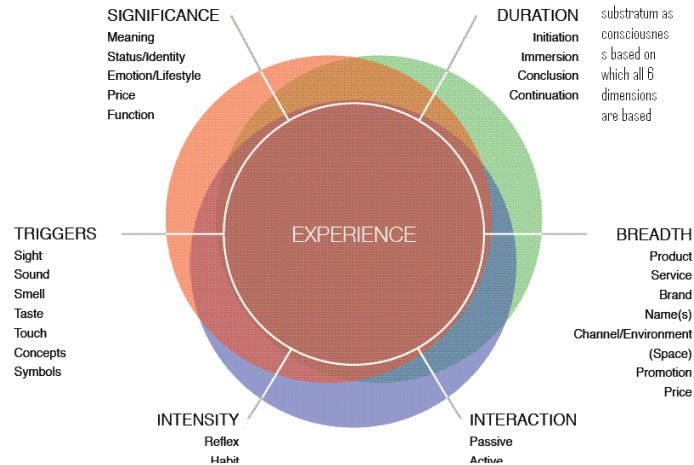


Figure 1 Depicting 7 dimensions of experience

User experiences are designed and it depends upon on the meaning, delight and usability characteristics of products, processes, services etc.

There are at least 7 dimensions of experience

- Time/duration
- Interactivity
- Intensity
- Breadth/consistency
- Sensorial, cognitive triggers,
- consciousness
- meaning

In other words, what it means to the design when a certain event occurs which may or may not be in the expected lines and what impact it has on the project can be known. There by adaptive designs enables to making meaningful experience designs.

Following is the example which gives an explanation on wisdom in making a decision

Data: 50

Information: Bearing capacity of soil at the ground site is 50 kpa .

Knowledge: The bearing capacity of soil is 80% below than the assumed value in design specification and based on the sub surface exploration there is no hard stratum available till 80 m depth.

Wisdom: Better adopt ground improvement technique such as sand drains or stone columns before going for spread foundation work.

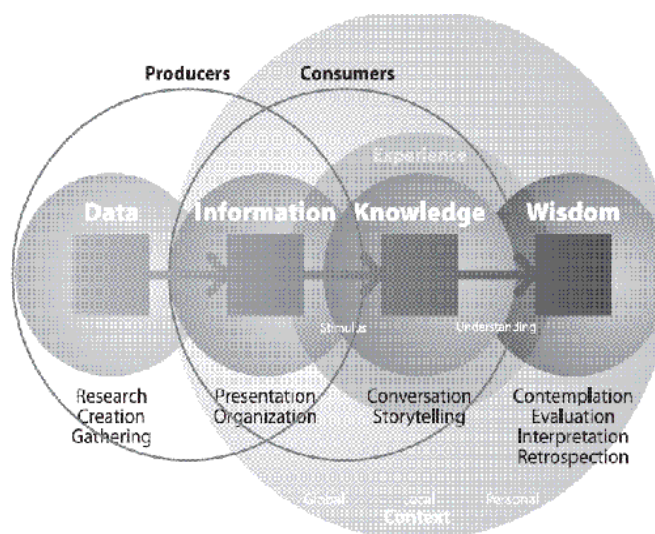


Figure 2 Picture depicting data, information, knowledge and wisdom, experience and context [7]

F. MAINTENANCE OF EXISTING STRUCTURES

In 1907 the accident of Saint Laurent bridge in Canada is attributed to misinterpretation of signals given by the structure before its failure [11].

Now a day's maintenance of existing structures is done by placing the sensors at the points where there is maximum risk of failure. The data which is sent by the sensors are analysed by humans. Using semantic web technologies the impact of the data received by the sensors can be analysed by software agents and if required based on the criticality of received data design changes can be done adaptively and appropriate warning mechanisms can be adopted, so that misinterpretation can be avoided.

G. RISK MANAGEMENT

Vision 2025 outcome 4 states that “Entrusted by society to create a sustainable world and enhance the global quality of life , civil engineers serve competently , collaboratively, and ethically as master”.

Managers of risk uncertainty caused by natural events, accidents and other threats

Risk refers to expected value of an unwanted event which may or may not occur. The expected value of negative event is the product of probability and some measure of its severity.

Natural events can be

1. Cyclones 2. Floods 3. Surge 4. Earthquake 5. Ground motion 6. Structural failure

Problem is that in the initial design, goals are set in an uncertain world and routine applications of factors of safety and other uniform standards may do little to reduce risk.

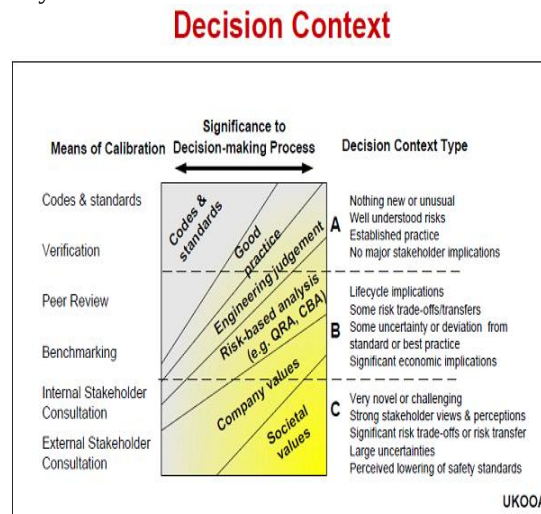


Figure 3 Depicting decision contexts [8]

It is in zone of B and C there are uncertainties and it is here that adaptive design will be of help. There is need for quality risk management guidelines for infrastructure industry. In general a risk management process comprises of initiation, risk assessment, risk treatment, risk review, and risk communication phases as described in the figure4

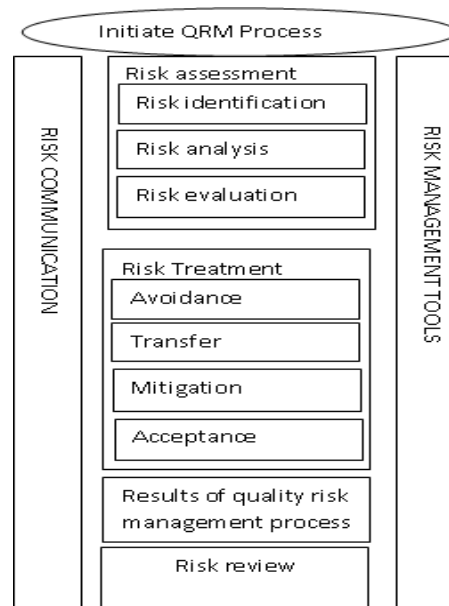


Figure 4 Depicting Risk Management Process

Risk Assessment: Following are the risk factors for infrastructure projects [Dr Hiren M.Maniar]

- a) Delay in approval: With time cost also increases, with cost the design alternative can take place in an adaptive manner by taking into account functional and quality requirements of the project.
- b) Changes in law: Changes in country's laws may also increase in time and cost constraints. With changes in law the design alternative need to be evaluated in an adaptive manner.
- c) Cost overrun: Inefficient delivery mechanism may incur upon cost overrun. With design fixed which cater to the functional and quality requirements, the impact on cost over run on other aspects of the project like finance etc can be assessed by having designs based on owl, rdf etc.
- d) Land acquisition and compensation: Much of the time is spent on collaboration with different entities of government agencies. The time to collaborate can be reduced by the usage of owl, rdf technologies which in turn has an effect on choice of design alternatives.
- e) Enforcement of contracts: Not all contractual provisions can be remembered and applied to the context of application by the project manager. Non compliance of contractual provisions and its implications on design can be evaluated in an adaptive manner.
- f) Construction schedule: Cost of the project has a bearing on the construction schedule. In turn based on cost constraints the design can be done in an adaptive manner taking into consideration the functional, quality and other requirements.
- g) Environmental risk: Environmental protection provision has a direct impact on the design requirements. If the environmental risk profile changes due to unwarranted event then designs need to change adaptively. The impact of change in the risk profile need to be assessed controlled and reviewed periodically.
- h) Human Factor: September 11, twin tower disaster confirmed that besides natural hazards in relation to the resistance of the structures, human factor, including terrorist behaviour need to be accounted for more and more seriously [11]. Impact analysis based on semantic web technologies can be performed by taking into consideration above scenarios and design can be performed to minimize the extent of damage in case of the realisation of the risk.
- i) Fire Hazards: Various accidents recently occurred in European tunnels (Channel tunnel, Mont – Blanc tunnel with 39 deaths, Gothard tunnel with 11 deaths) showed that relatively few concern about fire hazards existed in civil engineering [11]. Using the semantic web technologies an ontology can be created which takes into account the risks caused due to fire, water, wind, lighting etc. and impact analyses can be performed and can be considered in design.

Risk Analysis:

Risk analysis tools such as failure mode and effect analysis (FMEA) , a failure mode effect and criticality analysis (FMECA) or hazard analysis .

FMEA:

A FMEA is a systematic approach for analysing a system in order to identify the potential failure modes and their causes and effects on system performance. During FMEA, potential failure modes, their associated causes and effects of failure are systematically identified. An FMEA can be extended to FMECA, where the probability of failure with respect to its cause, detect ability of failure and severity of an effect of failure are investigated. To evaluate the risk of failure mode, an assessment is made by calculating the risk priority number. For this purpose, numerical values are assigned for the probability of occurrence(P),detect ability of failure(D) and severity of effect(S). Multiplication of P,D,S gives risk priority number(RPN).RPN is the characteristic of the residual risk and can be considered as acceptable[9]. If RPN is too high then, risk treatment measures can be considered. In addition risk management facilitation methods such as cause and effect diagram (also known as ISHIKAWA diagram or fish bone diagram)

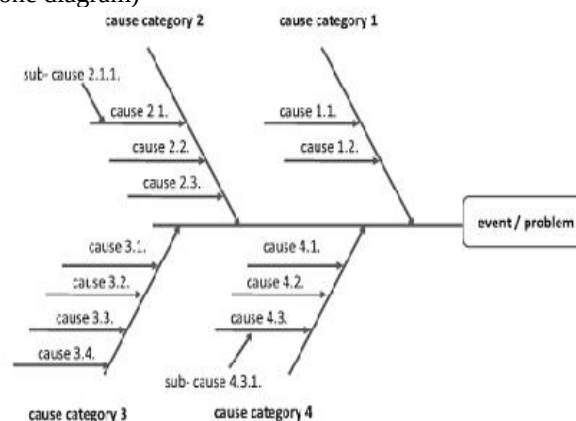


Figure 5 Depicting ISHIKAWA diagram [9]

H. ADAPTIVE DESIGN

Now a day design is not restricted to technical soundness, economy and quality aspects alone. The design need to comply and change adaptively, quickly with the changes in environment protection provisions, changes in the code provisions, changes in conditions at site (deviation from what is assumed during design and what the actual reality is in the field), unavailability of specified components at site but with availability of components of different specifications, changes in contractual provisions, changes in energy management system (ISO 500001), Experience design etc.

The risks assessment, analysis and its impact need to be evaluated on the project with the changing conditions so that delivery effectiveness of project is improved. Failure of the structure, accidents can be avoided.

Definition

Adaptive design is the design which takes into account the following

- 1) Risks arising due to the following changes or non compliance and performs design quickly, adaptively, and collaboratively at the site where the construction engineer can make better decisions.
 - Changes and non compliance of provisions of inter related entities of system such as technical code provisions, contractual provisions, energy management system, quality management system, country laws, human factor etc.
 - Changes in conditions at site (deviation from what is assumed during design and what the actual reality is in the field)
- 2) Meaning of the risk in case of its realization and its impact on the project. Also it enables experience by design

IV. Conclusions

Now a days, design is not restricted to technical soundness, economy and quality aspects alone. The design need to comply and change in adaptive manner, quickly with the changes in environment protection provisions, changes in the code provisions, changes in conditions at site (deviation from what is assumed during design and what the actual reality is in the field), unavailability of specified components at site but with availability of components of different specifications, changes in quality management and energy management provisions, design by experience which takes into account the human factor etc.

With the advent of new technologies like semantic web (owl, RDF, sparql, swrl), it now possible to have flexible, efficient, agile design.

By using ontology based applications which consider the shared meaning of provisions of code, accidents can be avoided which occur due to misinterpretation of code provisions.

Impact analysis of an event on the project helps to take preventive actions.

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