Risk reality vs risk perception

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Here we explore the feasibility of a rationalized approach to risk within construction procurement by considering explicit engineering risk and perceived risk that selective group of stakeholders share. In particular, the perceived risk is assumed to be dependent on motivational values that individuals identify with. The motivational values are evaluated using 40 questions Swartz Portrait Value Questionnaires. 10 selected hazards are considered in a survey to identify measure of fear and unknown that stakeholders recognize and data analysed. From the outcomes it was identified that by using the alternative approach to establish risk perception the priorities for the stakeholder group in terms of risk can be recognized. Furthermore, the outcomes could be used to target information to stakeholders or intervene to ensure that infrastructure performs according to expectation. As a result, it could become possible to revise what are currently inconsistent acceptable risk levels that have been embedded in active regulatory documentation.

Keywords: word; another word; lower case except names

Subject classification codes: include these here if the journal requires them

Introduction

Without doubt, risk has emerged in recent decades as a critical consideration in management, financial services but also in physical and biological sciences, engineering as well as for social scientists. Despite diverse formulations currently in use for risk the public policy in developed economies is striving to create a risk free environment in respect to health care, environmental protection, sustainability, etc. Realizing a risk free environment is clearly an impossible and a very expensive objective when built infrastructure is concerned. With the pressure for adaptation to changing climate, for sustainability and cost efficiencies it is inevitable that diverse understanding of risk among those participating in infrastructure procurement and the public will emerge as an obstacle to agreement on best policies. Once many interested parties are involved the problem of accounting, in a consistent manner, for their priorities and perceptions has to be addressed in respect to risk as well. Aven and Kristensen (2005) have established that current communication of risk leaves too much space for misunderstanding and mixture of objective facts with judgements and principles. Therefore, developing sound methodologies that can address the presence of many alternative formulations of risk and developing better risk communication format between parties that participate in built infrastructure procurement is of interest to us.

Both as a noun or a verb ‘risk’ is a frequently used term but could be easily misunderstood. It is sometimes intuitively accepted as a measure of the individual’s exposure to some danger (without being specific on the nature of that danger). Technical risk formulations on the other hand, are often rather explicit and expressed as a function of the likelihood of adverse event and its consequences. However, even for technical formulations Aven and Renn (2009) identified two categories for ten alternative descriptions of engineering risk, namely:

A. Risk expressed by means of probabilities
B. Risk expressed as a function of probabilities and consequences

It is easy to see that such categorisation is restricted as it implies quantitative measures (probabilities) and therefore access to large data that could only be available to experts. We can accept that above categories represent ‘technical’ risk and that category A is applicable when one is concerned with a distinct outcome and the category B refers to an event where sequence of outcomes (with different consequences) might be a concern. Here, understanding all parameters that contribute to risk descriptions as above is a formidable task, e.g. for infrastructure such as a road bridge due to inherent safety, probabilities of failure are very small (in most cases less than 10^{-4}) and consequences could be very diverse, from loss of life to traffic delay. Slovic (1998) has confirmed that risk controversies (arising between value judgement and technical analysis) require comprehensive approach that includes participation from a large number of interested parties. Furthermore, even in 1998 Pidgeon has pointed out to social science research that identifies importance of social, cultural and institutional processes to people’s evaluation of risk as well as fundamental value commitments that particular groups identify. He also drew attention to differences between ‘public’ and ‘professionals’ in respect to risk assessment criteria that have not been addressed in a consistent manner. Freudenburg (1988) challenged social scientist to engage with ‘the art of probabilistic risk assessment’ and provide quantitative estimates in form of probabilities as well as an insight into public perception of risk.

Consequently, as there are alternative formulations for technical risk, communication with no-technical public often represents a challenge. As a scenario we can consider a simple action of crossing the river where a toll bridge is in place (as an example of a standard infrastructure component). A member of the public walking along the bank has several options; not to cross, swim across, take a boat, use the tool bridge, etc. Surely, their decision will depend on environmental factors but it will include at least some risk recognition for each of the options. There might be some intuitive risk quantification imbedded within the decision process. Without specific numerical information the member of the public is acting on their perception of risk associated with options and subsequently deciding on the level that is acceptable to them. We really don’t know all parameters that influence this decision, utility, fear for life, lust, etc. However, professionals such as design engineers have knowledge about technical features of each of the above options but they will focus on their own requirements. It is a standard for engineers to consider alternative limit states when designing a bridge and also to consider risks associated with those limit states. For example for a bridge the engineer will quantify the likelihood that a sample limit state (e.g. deformation) is reached and identify associated consequences such as the scale of cracks opening, thus finding the technical risk measures. Such technical approach is still laden with assumptions about quantities but many other considerations that are a part of the ‘public’ scenario as above will not feature in the design process.

In this paper we explore if there is a scope to establish explicit mapping between the two broad understandings of risk, the technical and the non-technical view of risk. Such mapping would greatly contribute to better communication of risk for different stakeholders. This is a crucial issue as in developed countries numerous stakeholders for a single infrastructure can have very diverse priorities (profit, speed of delivery, sustainability agenda, etc.). Furthermore, for existing infrastructure that has been in use for some time there are increasing sources of data through monitoring, use of sensors, etc. that lend themselves to quantitative analysis. With availability of ever more sophisticated analytical tools, engineers could generate increasing quantitative information that can be used for evaluation of the technical risk. However, it has remained difficult to identify how to consistently communicate risk related quantitative information to the public.

Some further issues are of interest here, as Kasperson et al. (1988) have suggested. There is a distinct lack of integration between what some consider ‘technical analysis of risk and the cultural, social and individual response structures that shape public experience of risk’. They also established that it would be helpful to develop understanding how interaction between different ‘forms’ of understanding of risk lead to its social amplification with often negative impacts. Kasperson et al. (1988) confirmed that a large flux of information, through news and personal information channels, is an amplifier of risk. It is very easy to identify that since the late 80s the potential for social amplification of risk has greatly increased. At present, the number of information channels is significantly greater than in 1988 and it will be increasing in the future. In addition, the need for a rapid response through modern communication channels, swift technical risk assessments and effective communication are likely to emerge as a priority for many stakeholders. It is evident, as Slovic (1998) has pointed out that the new context is emerging in the modern society in the form of increasing public participation both in risk assessment and decision making.

Monetary and political pressures while influential are not in focus in this paper. Fischhoff et al. (1993) have considered issues with health risk and rightly identified that when we try to make assumptions about other people’s understanding of risk systematic data is needed and that method of acquiring data is detrimental. They identify a range of influences that can introduce heavy bias to risk perception when traditional data gathering techniques are implemented. The issues associated with understanding of the technical and perceived risk have also been considered by many specialists in the aviation and other industries however considering the specific nature of built infrastructure risk a direct application of methodologies is often difficult. Freudenburg (1988) was enquiring how can social scientists deal with probabilistic nature of risk assessment however, we pose an alternative question from the viewpoint of technical experts, how to communicate technical risk to diverse stakeholders?

Therefore, it is the aim of this paper to identify new tools that can lead to improved engineering risk communication both between professionals and between professionals and the public specifically in respect to built infrastructure risks.

Built Infrastructure Technical Risk

Built infrastructure expression could be used to refer to power supply systems, telecommunication systems but here, a more traditional components, such as bridges, roads, railways, etc. are assumed. These infrastructure components (systems in themselves) are often taken for granted by the wider public. It is only when faced with consequences of a major disruption caused by rare events such as an earthquake, or in the UK, sudden flooding that questions emerge about risks associated with built infrastructure and if those are acceptable to the public. While rare events attract attention of the public establishing acceptable risk levels in respect to normal operation is rarely talked about but it is possibly, more critical and has greater impact on day-to-day management of infrastructure. In some extreme cases when there is a pressure for cost efficiencies there will be inevitable effect on the engineering risk that public might become exposed to from the built infrastructure. Significantly, when there is a need to consider the effect that future climate scenarios might have on infrastructure there is a very strong case to make sure that the communication of associated engineering risk is effective. This aspect is of particular interest as changing conditions would result in changing outcomes for engineering risk so it is paramount to be clear what is technically acceptable but also what is the risk perceived to be acceptable by the public.

It is well known that procurement of built infrastructure from initial design to demolition at the end of the lifecycle is associated with uncertainty and in practice, engineers in particular, are using advanced analytical tools when uncertainties are present. The current technical practice is often to account for uncertainty using standard probabilistic analysis to establish quantitative measure such as the likelihood of the limit state occurrence. If we consider a traditional infrastructure as identified above the limit states have to be carefully defined to reflect the accuracy of structural models, physical variability, life cycle influences, etc. Then the engineering risk can be evaluated as a function of the probability of the limit state occurrence and the consequence of the limit state. The approximate First Order Reliability Method, is often implemented to evaluate the probability of limit states occurring in design and/or assessment as it is a method that reconciles uncertainty, physical models and data availability and current technology. Rule based expert systems have been widely implemented in many engineering applications to aid decision-making. Unfortunately, such expert systems have significant limitations due to the lack of flexibility in respect to evidence introduction and fixed output information.

In addition, when a new rule is introduced careful analysis is needed to establish its effect that is a challenge considering the complexities of built infrastructure. A more modern alternative, neural networks, has significant disadvantage that a new network is needed if any new variable is introduced therefore limiting their practical application for infrastructure where each component is site specific. Considering extensive uncertainty and considerable contribution of the specific site conditions on built infrastructure performance the communication of engineering risk remains an issue irrespective of the applied analytical approach.

In addition, for most existing infrastructure components the uncertainty in available data such as design stage information, records of construction, inspection records, abnormal load effects, etc. will be very high. There is also a distinct difference in the quality of data between sources of information, say for an existing road bridge loading variables such as the traffic volume and composition can be evaluated rather well using standard non-destructive instrumentation such as Weight in Motion (WIM). However, the infrastructure condition (strength of steel in the bridge girder) could only be estimated using an extensive sampling that is very expensive. Furthermore, the technical risk communication has to reconcile high uncertainty in respect to past and future exposure to the load, environmental effects, etc. If we refer to an existing highway bridge, likely future environmental conditions, maintenance and repair schedules will be highly uncertain and site specific. A relatively easy to understand consequence is the loss of life but not all critical conditions are associated with the loss of life and acceptability of consequences is evidently more complex problem where public perception of risk needs to be accounted for in engineering risk communication. Therefore it is evident that all these diverse circumstances affect the technical risk and they have to be acknowledged and communicated both between professionals and between professionals and the public.

Built Infrastructure Acceptable Risk

Once the technical risk is evaluated for built infrastructure it still remains to be established what is acceptable to different stakeholders that are associated with structure. For built infrastructure when engineers refer to performance they often think of the ultimate and serviceability limit states that are defined in the relevant regulatory documentation such as design standards, as the expected target performance. However, the engineering risk levels associated with these limit states are notional due to limited data the approximate nature of probabilistic analysis and variety of consequences that can arise from limit state realization. There is no regulatory documentation that would provide strict guidelines on acceptable engineering risk. As indicated earlier in respect to engineering risk definitions, Aven and Renn (2009), acknowledged that there is no significant evidence of converging agreement how to establish the acceptable engineering risk levels, considering fundamentally different nature of limit states. For example it is likely that the ultimate limit state would be associated with likelihood of fatality as opposed to the serviceability limit states that are far less critical in terms of fatality but more visible due to discomfort that they would cause to the public.

It has been a practice in the past to establish acceptable performance for built infrastructure in respect to past performance, as a comparative measure, Shafieezadeh and Ellingwood (2012). This has been the case with design codes where any new limit states were included with partial safety factors that ensure that certain levels of past performance are maintained. In the same way public regulatory bodies, such as the UK's Health and Safety Executive have implemented ALARP principles across industries for acceptable risk, therefore including construction, irrespective to the experience that such approach is more suitable to process industries where there is a substantial scope for data collection due to the repetitive nature of processes while each construction project is unique.

Recent revisions to the Flood and Water Management Act 2010 have altered the traditional approach to embankment dam assessment so that the driving principle has become that the failures are low probability high consequence events and therefore the acceptable risk associated with a dam failure is entirely the function of failure consequences. While this is now recommended practice for reservoir dams it is evident that such risk formulation is very simplified and as a result fatalities are unlikely to occur through failure of dams, however, significant costs could arise elsewhere (i.e. when there is no likelihood of the loss of life) due to disruption of services, flooding, pollution, loss of transport links, etc. The communication of these important issues has uniformly been poor and fragmented so there is no evidence that the general public has full understanding for the meaning of engineering risks and the role of regulation and codes of practice.

It is also difficult to find evidence that acceptable engineering risk levels have been co-ordinated between professionals or modified to account for public perception of risk. However, it is likely that in the near future increasing demands for transparency can be expected in respect to the target performance due to increasing data availability and technology advances. In addition, when the public bodies are seeking to transfer responsibility as has been the case in Public-Private-Partnership contracts those who take the responsibility on board would need to have in place sensible target performance in terms of engineering risk as well. This is highly significant for built infrastructure where stakeholders are a particularly diverse group. As the technical risk associated with infrastructure is most often represented as a quantitative measure that could be confusing to non-technical public it is inevitable that the public often finds it difficult to rationally accept or reject exposure to the given risk. We can recognise that risk acceptance is dependent to a large extent on risk perception for non-technical stakeholders and therefore effective risk communication has to address both quantitative and qualitative characterization of risk. The communication of these quantitative parameters to stakeholders has to be in the format that is understandable and that addresses their perceptions.

Risk Perception Modelling

Risk perception can be seen as a generic term but we will accept that it relates to individual's beliefs, attitudes, judgements and feelings in addition to their cultural and social disposition. It has been recognized for some time in psychological research that risk perception is a complex and as Wilkinson (2001) points out rather resistant, phenomena and different techniques have been established to identify main drivers when risk perception is concerned. While Wilkinson exposes limitations of empirical approaches to risk perception he also offers a rather comprehensive account of complexity of risk perception and evidence of its importance. For us it is of interest to identify tools that can capture risk perceptions from different stakeholders within the procurement processes associated with built infrastructure. In order to generate adequate data on stakeholder risk perceptions an appropriate research techniques need to be implemented, but those are not available as standard within engineering. However, Flynn et al. (1994) have implemented the psychometric paradigm to establish individual's risk perceptions and demonstrated the approach on a large sample (with multiple hazards and several dimensions). Recently, Nordensted & Ivanisevic (2010) identified that motivation values, while not precise, could provide a valuable insight into risk perceptions for well differentiated groups. In addition, Nordensted & Ivanisevic (2010) have confirmed that higher motivational values, Self-transcendence, Conservation, Self enhancement and Openness to Change can be identified as significant drivers in risk perception to the extent that they can be mapped to risk perception towards selected hazards for the specific demographics.

Motivational Values

Motivational values are considered a good measure to identify multidimensional function that reflects complexities of risk, as defined by Slovic (1998). Considering complexities of built infrastructure procurement and outcomes in terms of performance, utility, cost, etc. comprehensive representation of the diversity of stakeholders is essential. In addition, beyond the obvious threat of fatalities in case of collapse of built infrastructure multiple interests from investors, owners, stakeholders etc. are intertwined. The failure outcomes are also diverse and could include economic loss, failure in respect to the performance target, time delay, etc. therefore affecting very diverse stakeholders. These concerns are coupled with amplification effects that are almost unrecognizable from the 1998 perspective and explicit formulation of multidimensionality of risk is needed.

Long established research, Schwartz (1992), has shown in the past that demographic variables (gender, age, etc.) as well as educational background are reflected in motivational values. If we follow more recent evidence from Nordenstedt & Ivanisevic, (2010) we can further accept that motivational values (benevolence, universalism, self-direction, stimulation, hedonism, achievement, power, security, conformity and tradition) are useful for identification of risk perception as they transcend demographic boundaries. Relatively simple and widely accepted approach to evaluation of motivational values is Schwartz Portrait Value Questionnaire (PVQ), Schwartz (1992). Koivula & Verkasalo (2006) have implemented two alternative forms of Schwartz Portrait Value Questionnaires to establish their effectiveness. They have considered differences in motivational values between three groups of individuals in Sweden with different educational level and established that when students, white collar workers and manual workers have been asked to complete both forms of the survey it was possible to identify significant agreement with other historic surveys but also to identify differences in motivational values between the three groups.

There are many forms of PVQ questionnaire but the standard is the 40 question f from past evidence as successful as the respondents tend to engage with the question of their background. The questions are of the form that requires the respondents to express how much they are like a fictitious person. For each of the motivational values there are from 3 to 5 questions arranged in a random order to avoid the inertia in responses. Thus for the question:

> "He thinks it is important that every person in the world be treated equally. He believes everyone should have equal opportunities in life",

the respondent is asked to consider:

> "How much like you is this person"?

and respondents have an option to select one of six levels of agreement from:

> "Not like me at all up to Very much like me".

For relatively small samples such as a single group of stakeholders within the procurement the consistent approach would be to focus on the 4 higher order motivational values as defined in Table 1.

Table 1 Motivational values and higher order value types

Higher Order Motiva	Self Transcendence	Conservation	Self Enhancement	Openness to change
	Universalism	Conformity	Achievement	Self Direction
	Benevolence	Tradition	Power	Stimulation
		Security	*Hedonism*	*Hedonism*

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Risk perception

For some time, it has been an acceptable practice to implement a form of questionnaire that asks individuals to rate a number of hazards in order to establish their risk perceptions, Flynn et al. (1994). Furthermore, there has been evidence that dimensions of 'dread' and 'unknown' most significantly affect the perception of risk, Slovic (1998). To capture the risk perception between several countries for example, Nordensted & Ivanisevic (2010) implemented 20 questions format, 10 for each dimension of 'dread' and 'unknown' respectively. Sample hazards considered by Nordensted & Ivanisevic (2010) were AIDS, drinking alcohol, climate change, terrorism, fire in the home, motor vehicles, commercial airplanes, cancer, nuclear power plants and stress. The analysis by Nordensted & Ivanisevic (2010) has provided evidence that mapping between higher order motivational values and risk perceptions is possible and confirmed that such functionality could lead to further improvement in understanding risk perceptions for diverse groups. This is seen as a rather appealing feature for identification of risk perceptions within built infrastructure procurement so that risk communication both between professionals and between professionals and stakeholders in general could be improved.

Thus these techniques provide an opportunity to consider relatively small an
groups of stakeholders in the civil infrastructure procurement, capture their motiva
identify their risk perceptions. By considering such groups we should be able to
importance between motivational values for different distinct groups and benchmar
earlier and extensive studies. For example Koivula & Verkasalo (2006) have rep
importance that groups attach to Security and the close correlation between S
motivational values in particular for student group. The implication of these findings
Portrait Value Questionnaires do represent a viable tool to establish motivational v
dominant higher order ones) for specific stakeholder groups as we have in construct
therefore can be implemented as a rather rigorous background for us to investigate the in
order motivational values on risk perception for selected stakeholders that partici
infrastructure procurement.

Risk Perception Evaluation for a Specific Stakeholder Group

We consider a hybrid technique to establish motivational values and risk perc
the representation to two dimensions , dread and unknown for 10 different hazards).
confirmed, it is considered sufficient to limit focus on two dimensions to identify gen

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perception for a stakeholder group. The respondents can be asked to rate their fear (dread) within 7-point scale from ‘no fear’ to ‘very great fear’ (fear is sometimes used as more acceptable form of words). Within current investigation it was considered that there is no need to allow for the role of framing as it was not expected to have a significant influence on the relationship between the motivational values and risk perception. Therefore, rather than for usual demographics parameters we select a professional stakeholder group to establish their motivational values and risk perceptions. In or feasibility of mapping between stakeholder’s motivational values and their risk perceptions we focus on a selected group with particular graduate level technical qualification in civil engineering. As stakeholders in infrastructure procurement these engineers are likely to be experts that would establish acceptable engineering risk for the infrastructure but they would also engage in risk communication with other professionals and the public.

Thus, by selecting a particular stakeholder group additional attributes such knowledge are present within the group our expectation is that their risk perceptions would reflect those specific attributes. If we consider risk perception in respect to climate change this s would have the technical knowledge about the impacts that climate change can have on infrastructure in addition to the general knowledge and attitudes that are socially accepted in the socie we apply the psychometric paradigm to establish group’s risk perceptions in two dimensions, dread and unknown. As a result we aim to establish the value priorities and their risk perceptions. Outcomes would serve to improve our understanding of the stakeholder group’s risk perceptions and importance between motivational values.

Stakeholder Group Risk Perception Evaluation (Practical Example)

For example we have considered a group (36) that represents stakeholders in the procurement, graduate civil engineers. Therefore according to previous survey outcom Koivula and Verkasalo (2006) such group would have a distinct set of motivational values.

Firstly, the 40 questions Schwartz Portrait Value Questionnaire was implemented to identify group’s expressed motivational values. From the analysis of the questionnaire outcomes we have confirmed that our stakeholder group shares value priorities with students from the and Verkasalo (2006). For example our stakeholders have identified Universalism and Self-direction with highest mean values and low coefficients of variation. In terms of higher order motivational values we have found that:

- Self-transcendence emerged as the dominant higher motivational value with the highest correlations between answers. On the scale of 1 to 6 the mean response for all Self –

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Transcendence questions was 4.86 with modest standard deviations, e.g. as low as 0.79 for one of the questions. This is the strongest driver for the stakeholder group.

- Conservation questions emerged with mean response at 4.29, however with high coefficients of variation. The lowest standard deviation for Conservation questions was 1.09 but also as high as 1.89.
- It is a common practice to implement multi-dimensional scaling for large s we have found that the value of Security is in a particular manner logged between Conformity and Tradition in line with Schwartz (1992) survey, however it is also positioned almost opposing the Self Enhancement higher order motivational values (Universalism and Benevolence). This outcome is stakeholder group specific as for general population the expectation would be that Value of Security is aligned in a different way.

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Sample mean values for our survey answers (using the scale 1-6) are included in Tabl

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The processing of risk perception survey considered two dimensions 'dread' and choice of answers that were scored on the scale 1 to 7, where 1 represents 'no fear' or all' and 7 represents 'very great fear' or 'well informed'.

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Considering the dimension 'dread' in terms of answer mean value for each haza is shown in Figure 1. It is evident that Cancer is perceived to be the highest risk. benchmark the outcome in Figure 1 except in terms of ranking of risks. To that effect our stakeholder group has considered drinking alcohol as very low risk while general American population survey in Flynn et al. (1994) ranks risk from drinking alcohol ahead of Commercial Air Travel, Climate Change and Nuclear Power Plants. This is an important finding as it emerges that it is possible to identify risk perceptions for particular stakeholder groups. Thus in combination with values research there is a scope to investigate multiple stakeholder groups within built infrastructure procurement and identify differences in their risk perception so that it can become possible to define a methodology to overcome those discrepancies and by implication improve the risk communication. It is helpfu survey outcomes reflect those for general demographic sample identified across several nations and shown in Nordensted & Ivanisevic, (2010), where odds ratios in respect to selected hazards have been established for particular dominant higher order motivational values.

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We have selected a subset of relevant risks that could be of interest to the infrastructure procurement to follow the outcomes for our stakeholder group between dimensions of 'dread' and ‘unknown’. Sample outcomes are presented in Table 2. It is evident that climate change is perceived as lower risk despite lesser ‘knowledge’ about the hazard then for nuclear power plants. This can have implications in practice. Both in design and assessment when decisions are made on significant limit states the engineering risk is a technical measure and the acceptable levels have to be agreed and communicated. Furthermore as these technical measures are notional and could only be used in comparative manner the clarity and consistency in risk communication is obviously crucial. *For these specific hazards the implication of risk perception within the group could mean lower safety factors in respect to Climate Change and as a result higher probability of mitigation costs emerging later as a result of changing climate impact.* Significantly, if selection is needed in respect to future climate scenarios perceived risks will reveal particular effects of the projected climate change that need to be addressed and communicated beyond technical stakeholders. In such circumstances it is of utmost importance to capture risk perceptions of different stakeholders and address any discrepancies that might be present.

Table 2 near here

Our sample group identified nuclear power plants as representing significantly climate change, motor vehicles or commercial aeroplanes but also revealing that their understanding of risks associated with climate change is much higher than about nuclear power plants. Intuitively one would expect that the group is aware of high levels of uncertainty associated with climate scenarios and the very cautious approach to design and operation of nuclear power plants and at mo two risks in reverse order. These contradictions are in line with Slovic (1998) and investigating risk perceptions for distinct stakeholder groups would be very beneficial for risk communication. It is possible that, as a consequence, of the stakeholder risk perception mapping the infrastructure target risk levels in design, construction, assessment and in-service will mapped to address stakeholder risk perceptions but also that more sophisticated risk c wider public can be established. These findings support the view that risk regulation would be welcome and that risk management could benefit from social scientist’s understanding of risk perception, Pidgeon (1998). Our sample is small but there is no evidence that technical knowledge alters th and this finding is very important for risk mitigation and communication.

Fischhoff et al. (1993) have identified problems that can prevent full appreciati risks as well as weaknesses of intuitive approaches to risk communication and our ou good base to identify where understanding of quantitative measures of risk is lackin effective risk communication strategy that is important in many industries.

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Furthermore, we have focused on nuclear power plants and climate cha and related those two hazards to familiar and well used transportation i.e. commercial airplanes and motor vehicles. What is striking is that fo constrained sample such as the one that was considered, with distinct h order motivational values there is no visible functional dependence bet how well informed the individual is and their risk perception associate the hazard. It might be the utility that has significant influence over on perception of risk. In our case

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Risk perception within built infrastructure regulation

The relevance of our enquiry is most significant for those trying to regulate processes integral to procurement of built infrastructure. Complexities of stakeholders approach to risk have always been evident but here they are in a distinct way quantified, therefore enabling ranking, selection, etc. between risks. For technical regulation such as design codes etc. regulators aim to relate current risk to past performance or at least reduce it to a very low level. On one hand these are positive aims but, in reality and on evidence presented here, require agreement of many parties. We have focused on risk perception and risk acceptability however there are further concerns, regarding the risk relevance, risk mitigation, etc.

For illustration we can relate regulatory situations and challenges by referring back to revised Flood and Water Management Act 2010 to demonstrate the need for structured appr
of acceptable built infrastructure risk. As a consequence of the Act a rather large number of very old dams with mostly incomplete records about their design, current condition, maintenance, assessment, etc. will need to be assessed in terms of risk that they pose to the vicinity. It has been demonstrated by Preziosi & Micic (2012) that if, in addition to current status, future climate scenarios are considered relatively harmless projections could increase substantially the engineering risk associated with small homogenous embankment dams. While technical expert's expectation might be that an increase in likelihood of adverse event will be mirrored in perception of high risk among members of the public the latter are unlikely to share their view as evidence from Flynn et al (1994) and Nordenstedt and Ivanisevic (2010) demonstrate. At present, not only that there is a limited guidance on establishing site specific acceptable engineering risk levels, risk communication as well is not addressed as an integral matter. If there is no differentiation between sites and modes of failure strictly defined probabilities of limit states occurring could mean enormous programme of strengthening that is most likely unnecessary but at the same time more frequent non-fatal but significant problems associated with serviceability limit states being breeched and potentially significant strife between various stakeholders. It is inevitable that only through further development the mapping between higher order motivational values and risk perception could bring significant benefits. We have been able to establish a core methodology
stakeholder group specific data on relationship between motivational values and risk p
way it should be possible to identify multiple relationships between specific higher m
and risk perceptions. The selection of distinct stakeholder groups could be informed f
by Slovic (1998) but also by recent social surveys and multiple data sources that are em
rightly pointed out involvement of a larger group of interested and affected ci
acknowledged and accommodated irrespective of the complexity of such endeavour. Our methodology is able to establish, an explicit measures for perceived risk and therefore there is an opportunity to extend this approach to investigate acceptability of risk. It would be constructive to establish if motivational values have a major influence on the latter as well.

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There is also a distinct scope for development of additional quantitative models that could include engineering risk in regulatory documentation. This aspect is of particular interest to technical community for the purpose of performance based design. Such design situations arise currently with many high complexity projects (very tall buildings, nuclear power installations, transportation projects, etc.) where design criteria have to be project specific in addition to regulatory requirements

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significant improvements in consistency and efficiency in infrastructure procurement can be expected. The main issue remains to find appropriate forms of mapping between quantitative and descriptive outcomes. While for a small scale problem (such as the homogenous earthfill embankment dam) this might appear feasible to achieve for diverse systems often associated with built infrastructure this will represent an area where significant contributions are expected.

While in design it is sometimes the case that the performance is the guiding principle in assessment of existing structures this is always the case and with inclusion of additional risk measures we will enable life cycle of structures that is less expensive with risk levels proportional to the purpose rather than arbitrary, historical, levels. For existing infrastructure, owners currently pursue a predetermined sequence of well defined inspection, maintenance and repair activities. However, there is an increasing evidence that such processes are inefficient and new management strategies for changing priorities in respect to the infrastructure could emerge on the basis of the current work.

Conclusions

In order to investigate risk perceptions associated with built infrastructure we have ventured away from standard engineering practice and implemented an alternative methodology that integrates analysis of motivational values and risk perception. It was possible to establish the motivational values for a sample group of construction associated stakeholders using 40 question Schwartz Portrait Value Questionnaire (PVQ). The outcomes in terms of strong motivational values were in line with previous research of groups with comparable demographics. Risk perceptions were established using conventional survey method where 10 hazards were considered. Our current work has confirmed that such approach can efficiently identify motivational values of the specific stakeholder group and establish group's rank between particular risks. Through further development differences in risk perceptions between stakeholder groups could be identified. For low probability events that are associated with built infrastructure a useful source of information would become available to those who wish to communicate technical risk evaluations.

It is of significant benefit that new availability of quantitative measures for risk perception for built infrastructure related processes such as design, assessment, inspection, could be reviewed and adapted to improve performance. Ultimately, an explicit methodology to establish site specific performance requirements that reflect the site specific risks with expectations of stakeholders might be feasible. This does not mean that risk perceptions would need to be evaluated every site and every stakeholder group it is much more the case for updating of general procedures that are present in procurement of built infrastructure. From extensive studies of different stakeholders and diverse risks, risk perception would become a parameter routinely taken into account.

It is important to stress that our findings are of great importance when risk communication is concerned. It is evident that beyond technical risk information communication has to echo stakeholder's motivational values and overcome effects of social amplification within modern society.

Despite the modest scale of the survey it is identified that the approach to risk in general in construction industry is sometimes too conservative and as a consequence too expensive and not sustainable. If the new approach to risk perception characterization is implemented across different technical disciplines, design and, by extension, assessment can be significantly less constrained. We expect that as a result of this research structures would be safe and fit for purpose.

We have explored the scope for improved communication of risk and implicitly we are making a positive contribution to potential risk reduction.

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