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The influence of engineering designers on health and safety during construction

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Relative to other industries in South Africa and construction industries worldwide, the construction process generates a disproportionate number of fatalities, injuries and disease, the direct and indirect cost of which contributes to the cost of construction.

Designers influence health and safety (H&S) directly and indirectly. Directly as a result of design, supervisory and administrative interventions and indirectly as a result of type of procurement system used, prequalification, project time, partnering and the facilitating of pre-planning.

The purpose of the paper is to present the results of a study conducted among engineering practices in South Africa to determine their perceptions and practices relative to H&S. The following constitute the salient findings. Quality, public H&S, schedule and cost are more important than H&S. H&S is considered/referred to on most design, procurement and construction occasions. A number of procurement-related situations and actions that negatively affect H&S are often encountered and a number of design, procurement and construction actions could contribute to an improvement in H&S. Experience predominates in terms of the means by which H&S knowledge was acquired.

INTRODUCTION

Construction occupational fatalities, injuries and disease result in considerable human suffering and affect not only the workers directly involved, but also their families and communities. A further impact is the contribution to the national cost of medical care and rehabilitation (Smallwood 1996).

However, occupational fatalities, injuries and disease also contribute to variability of resources, which increases project risk. Such risk can manifest itself in damage to the environment, reduced productivity, non-conformance to quality standards and time overruns, and ultimately in an increase in the cost of construction. Other possible manifestations include damage to client property, impaired production processes and a poor client and contractor image as a result of accidents (Smallwood 1996).

Traditionally, project success has been assessed relative to cost, quality and time. However, this traditional approach has generally not been successful, with the greater percentage of projects not being completed within budget and to quality and time requirements (Allen 1999). The need for a paradigm shift and focus on H&S is amplified by the complementary role of H&S in overall project performance cited by various authors – H&S enhances productivity, quality, time and, ultimately, cost (Hinze 1997; Levitt & Samelson 1993).

Given the documented impact of accidents, the influence of H&S on other project parameters, the need for a multi-stakeholder approach to H&S, the status afforded to H&S by tertiary engineering programmes, and the number of slab and other collapses in recent years in South Africa, a study 'The influence of engineering designers on health and safety (H&S)' was conducted. The objectives of the study were to determine the

- perceptions of engineering designers relative to the importance of H&S and other project parameters
- frequency at which engineering designers consider and refer to H&S during the design and development, and implementation or construction phases
- frequency at which engineering designers consider and refer to H&S relative to various design and related activities
- frequency at which various procurement related situations and interventions which affect H&S are encountered and taken by engineering designers respectively
- aspects or actions which engineering designers perceive can improve or contribute to an improvement in H&S performance, and
- the perceived impact of inadequate or the lack of H&S on other project parameters

For reasons of brevity the paper only addresses the second and third phases of the project life cycle, namely design and development, and implementation or construction, hereafter referred to as design and construction.

Cost of accidents

The cost of accidents is frequently cited as a major motivation for addressing H&S (Hinze 1997). The cost of accidents can be categorised as being either direct or indirect. Direct costs tend to be those associated with the treatment of the injury and any compensation offered to workers as a consequence of being injured. Indirect costs, which are borne by contractors, include reduced productivity of the workforce, clean-up costs, and wages paid while the injured is idle (Hinze 1997). Research indicates the total cost of accidents to constitute 6,5 % of the value of completed construction (The Business Roundtable 1995) and approximately 8,5 % of tender price (Anderson 1997). A further motivation is the synergy between H&S and other project parameters of cost, environment, productivity, quality and schedule.

Relationship between H&S and quality

Quality, which means conformance to requirements, amplifies the need for H&S, as conformance to requirements entails, inter alia, conformance to SABS and other contractual requirements, legislation and, if applicable, ISO environmental, H&S, and quality management systems (QMSs). Consequently, an activity or project cannot be said to be successful if disabling injuries or fatalities have been incurred during the process (Hinze 1997). A further aspect is that injuries and fatalities are not project requirements and, consequently, constitute defects. The findings presented in the investigation report into the Injaka Bridge collapse of 6 July 1998 (Department of Labour 2002) reinforce and amplify the relationship between quality and H&S, and bear testimony to the implications of non-conformance to requirements and the lack of adequate quality and other management systems.

The need for QMSs is not constrained to construction. According to Cornick (1991) there are a number of incentives for design practices to implement QMSs in their practices, for example reduced liability risk because of a reduction in professional indemnity insurance premiums. This occurs as a result of the systematic discipline demanded of any process by the application of a QMS:

- Client requirements are clearly defined and agreement thereof is recorded.
- Sources of information pertaining to any design decision are clearly defined and documented.
- Responsibilities for project quality are clearly defined and documented.
- There is reduced supervisory responsibility relative to the construction process.

Synergy

Research conducted among project managers in South Africa investigated the impact of inadequate H&S on various project parameters. Productivity (87,2 %) and quality (80,8 %) predominated, followed by cost (72,3 %), client perception (68,1 %), environment (66 %), and schedule (57,4 %). H&S is a prerequisite for productivity and quality as housekeeping, inter alia, complements access and ergonomics. Accidents result in increased cost, damage to the environment and can substantially retard project progress as a result of either, decreased productivity or a cessation of the works. Client perception may be adversely affected by accidents, as they may stipulate specific H&S-related contractual requirements, particularly in the case of projects in or adjacent to an existing facility (Smallwood 1996).

Legislation / international agencies

The Occupational Health and Safety Act (OH&S Act) (Republic of South Africa 1993) schedules comprehensive requirements for employers such as contractors. However, Section 10 allocates responsibility to designers to ensure that any 'article' is safe and without risks to health.

The Construction Regulations (Republic of South Africa 2003) lay down important requirements with respect to clients and designers.

Clients shall, inter alia,

- prepare H&S specifications for the construction work
- ensure that principal contractors have made provision for H&S costs in their tenders
- provide principal contractors with any information that might affect H&S
- appoint principal contractors for projects
- ensure that principal contractors implement their H&S plans
- stop work that is not in accordance with the H&S plans, and
- ensure that sufficient H&S information and resources are available to the principal contractor where changes to the design or construction are made

Designers shall, inter alia,

- make available all relevant information about the design such as the soil investigation report, design loadings of the structure, and methods and sequence of construction
- inform principal contractors of any known or anticipated dangers or hazards or special measures required for the safe execution of the works, and
- modify the design or make use of substitute materials where the design necessitates the use of dangerous structural or other procedures or materials hazardous to H&S

The International Labour Office (1992) specifically states that designers should

- receive training in H&S
- integrate the H&S of construction workers into the design and planning process
- not include anything in a design which would necessitate the use of dangerous structural or other procedures or hazardous materials which could be avoided by design modifications or by substitute materials, and
- take into account the H&S of workers during subsequent maintenance

The influence of design

According to Jeffrey and Douglas (1994) it has to be accepted that there is a causal link between design decisions and safe construction. This is based on research conducted by the European Foundation for the Improvement of Living and Working conditions, which concluded that 35 % of site fatalities were caused by falls that could have been reduced through design decisions. Schneider and Susi (1994) say that constructing a new building is, by its very nature, a problem in ergonomics as construction involves work at floor and ceiling level requiring kneeling, bending, reaching out, twisting and the adopting of uncomfortable work postures.

Designers influence H&S directly through design specific, supervisory and administrative interventions. Design specific interventions include

- concept design
- general design
- selection of type of structural frame
- site location
- site coverage
- details
- method of fixing, and
- specification of materials and finishes

Supervisory and administrative interventions include

- reference to H&S upon site handover and during site visits and inspections
- inclusion of H&S as an agenda item during site meetings, and
- the requiring of H&S reporting by contractors

Designers also influence H&S indirectly through

- type of procurement system used
- prequalification
- project time
- partnering, and
- the facilitating of pre-planning (Smallwood 2000b)

A further role identified for designers is that of optimal interaction with clients, particularly at the design brief stage. This is the most crucial phase for the successful and healthy and safe completion of any project. Deviations from it at a later stage resulting in variation orders can be the catalyst that triggers a series of events from designer through to workers that culminate in an accident on site (Jeffrey & Douglas 1994).

Designers also influence the pre-planning of H&S. Pre-planning identifies all the ingredients of and resources required for the H&S programme to be effective and efficient. However, the design of a project is a great influence on determining the method of construction and the requisite H&S interventions. Consequently, designers need to make sufficient design-related information available at pre-project stage to facilitate budgeting for adequate resources (Liska 1994).

Constructability is a further design related issue. 'Design for safe construction' is one of 16 constructability design principles listed by Adams and Ferguson (McGeorge & Palmer 2002). However, most of the other 15 principles are indirectly related to, and consequently influence, H&S. Method of fixing, size, mass and area of materials, position of components, inter alia, amplify the relevance of constructability to H&S.

Procurement-related issues

Procurement systems are important as they affect contractual relationships, the development of mutual goals, the allocation of risk, and ultimately provide the framework within which projects are executed (Dreger 1996). The traditional construction procurement system, which entails, inter alia, the evolution of a design by designers, the preparation of bills of quantities and related documentation by quantity surveyors and the engagement of a contractor through competitive bidding, invariably on the basis of price, does not complement H&S. This may be due to the separation of the design and construction processes, the incompleteness of design upon both preparation of documentation and the commencement of construction, and the engagement of contractors on the basis of price (Rwelamila & Smallwood 1999).

Competitive tendering marginalises H&S. Market conditions in South Africa are such that contractors frequently find themselves in the iniquitous position that should they make the requisite allowances for H&S, they run the risk of losing a tender or negotiations to a less committed competitor (Smallwood 1996). Fryer (1997) says that clients may have to accept that there is an 'H&S premium' to pay in the cost of construction. During research conducted in South Africa approximately 50 % of project managers advocated the inclusion of a provisional sum for H&S (Smallwood 1996). This would ensure that all tenderers allocate an equitable amount of resources to H&S.

South African contract documentation generally does not engender H&S. Although references are made to H&S in standard contract documentation, such references are primarily in the form of specific reference to the Occupational Health and Safety Act. In many cases they can be described as indirect, hardly coercive and, depending upon the level of commitment, contractors continue to address H&S to varying degrees (Smallwood & Rwelamila 1996).

Project duration also impacts on H&S. A shortened contract period may result in a project duration that is incompatible with the nature and scope of the work to be executed (Hinze 1997). Hinze (1997) also cites pressure to meet unrealistic deadlines as a common source of mental diversion which diversion increases the susceptibility of injury.

Various authors, inter alia Levitt and Samelson (1993), advocate prequalification of general contractors and subcontractors on H&S by clients and general contractors respectively. The purpose of prequalification in the H&S sense is to provide a standardised method for the selection of contractors on the basis of demonstrated safe work records, H&S commitment and knowledge, and the ability to work in a healthy and safe manner. This will ensure that only H&S-conscious contractors are selected.

Construction phase

Various processes, strategies and interventions that can complement H&S can be implemented during the construction phase.

Partnering is a process that brings the various stakeholders involved in a project together: client, designers, general contractors, subcontractors and suppliers. The process entails the developing of mutual goals and mechanisms for solving problems. There are two reasons for expecting partnering to reduce accidents. First, the improvement in all-round relations on the project, which in turn, according to research, results in reduced accidents. Second, the performance objectives, which form part of the partnering charter, usually include a specific mention of H&S (Levitt & Samelson 1993).

Given that engineering designers often fulfil the function of principal agent and practise as project managers, various project management-related H&S literature is referred to. Oosthuizen (1994) maintains that project managers will be successful in their endeavours if they adopt a holistic approach as H&S, productivity and quality are inextricably intertwined. Ideally, project managers should make frequent reference to H&S on all occasions during the construction phase, namely site handovers, meetings, inspections and discussions, to ensure that the project environment is conducive to and complementary to the synergy between H&S, productivity, quality and time (Smallwood 1996).

Risk

During research conducted in South Africa, 95,8 % of project managers maintained that inadequate or the lack of H&S increased project risk (Smallwood 1996). Inadequate or the lack of H&S results in variability of resource output and consequently an increase in risk. However, it also increases the probability of an accident. Furthermore, given that, first, risk is a function of probability and impact, and second, the outcome of accidents is largely fortuitous, the potential risks as a result of inadequate or the lack of H&S are substantial.

Engineering construction H&S education

Smallwood (2002a) surveyed 21 South African Departments of Civil Engineering attached to thirteen technikons and eight universities – 52,9 % of departments included construction H&S in their programmes, while 53 % of respondents perceive construction H&S to be less than important / important, and 47 % more than important / very important. Twenty-two potential H&S subject areas were addressed by on average 36,4 % of responding departments. Between 0 % and 33,3 % of responding departments addressed twelve subjects areas, between 33,4 % and 66,7 % addressed six subject areas, and more than 66,7% addressed three subject areas. The influence of procurement systems was not addressed at all. The findings indicate that graduate civil engineers are not optimally empowered to contribute to or manage construction H&S.

RESEARCH

Sample stratum

The sample stratum consisted of 802 member practices of the South African Association of Consulting Engineers (SAACE). Only practices providing services relative to the following categories were included in the sample stratum; building services, civil, electrical, geotechnical, mechanical, structural and project management. Ninety-seven questionnaires were included in the analysis of the data, which constitutes a net response rate of 12,2 %.

Analysis

The analysis of the data consisted of the calculation of descriptive statistics to depict the frequency distribution and central tendency of responses to fixed response questions to determine respondents' perceptions with respect to the extent to which performance could be improved relative to various

indicators/measures, the extent to which aspects/factors/interventions affect performance, and the extent to which such aspects/factors/interventions could contribute to an improvement in performance.

To rank fixed response items according to the central tendency of responses, importance indices (II) with values varying between a minimum of 0,0 and a maximum of 4,0 were calculated as follows:

Unsure, Not important / Never/ Minor extent (n_0), Less than important / Rarely / Near minor extent (n_1), Important / Sometimes / Some extent / (n_2), More than important / Often / Near major extent (n_3), Very important / Always / Major extent (n_4) questions:

$$II = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4}{n_0 + n_1 + n_2 + n_3 + n_4}$$

It should be noted that the *unsure* (n_0) responses were not included in the denominator equation to compute the IIs presented in tables 3 and 4.

Findings

On average, respondents' practices employed 9,7 engineers and 14 engineering technicians.

The following disciplines of engineering are represented by respondents' practices: civil (75 %), electrical (24 %), geotechnical (24 %), mechanical (19,8 %), structural (60,4 %) and other (10,4 %). Given that there is a substantial relationship between structural design and construction H&S, the percentage respondents representing the structural discipline is notable.

Respondents' practices provided engineering design/supervision services for the following types of construction in 2001: infrastructure (86,5 %), commercial (59,4 %), industrial (56,3 %), domestic (34,4 %) and other (3,1 %).

Table 1 indicates the importance attached to traditional and non-traditional project parameters to respondents' practices in terms of percentages relative to importance on a scale of 1 (not) to 5 (very), and a ranking based upon the II value. Given that all the project parameters have II values above the midpoint value of 2,0, the parameters can be deemed to be important to practices. It is notable that four of the five project parameters have II values > 3,2, which indicates that they are perceived to be between more than important to very important / very important. It is significant that project H&S, the subject of the study, falls outside this range and ranked fifth. It is notable that the three traditional project parameters (quality, schedule and cost) achieved rankings in the top four. However, the II value of project quality, which achieved the highest ranking, is somewhat higher than that of the second-ranked public H&S. Project quality and public H&S probably achieved the rankings of first and second due to their impact on structural integrity and the performance of structures and infrastructure in general.

Table 2 presents the frequencies at which practices consider or refer to construction H&S on fourteen occasions in terms of the frequency range, never to always. It is significant that the values of twelve of the fourteen IIs are above the midpoint value of 2,0, which indicates that the consideration of or reference to H&S on these occasions can be deemed to be prevalent – site meetings, site inspections/discussions, and site handover predominate. It is notable that the highest-ranked 'upstream' occasion, preparing project documentation, was ranked fourth, followed by detailed design and working drawings. In general practices can be deemed to consider/refer to H&S.

Table 3 presents the frequencies at which practices consider/refer to construction H&S relative to sixteen design-related aspects, in terms of the frequency range, always to never. It is significant that thirteen of the sixteen II values are above the midpoint value of 2,0, which indicates that the consideration of / reference to H&S relative to these design-related aspects can be deemed to be prevalent. Specification, method of fixing, design (general) and details predominate. Given that certain materials contain hazardous chemical substances, it is notable that content of material achieved a ranking of seventh. Given that materials handling, and more specifically the mass of materials, contributes to manual materials handling, it is also notable that mass, edge, surface area, and texture of materials achieved rankings of twelfth, thirteenth, fifteenth and sixteenth respectively. However, schedule and finishes, which encapsulate materials and processes, achieved rankings of tenth and fourteenth respectively.

Table 4 indicates the frequency at which various situations that impact on H&S arises in terms of percentages relative to the frequency range never to always. It is significant that eight of the nine II values are above the midpoint value of 2,0, which indicates that the achieving/ encountering/use of the situations/states /actions can be deemed to be prevalent. It is also significant that the top four ranked situations/interventions/actions are cited by literature as having a negative influence on H&S: competitive tendering, variation orders, drawings are revised, and clients revise their requirements. Similarly, with respect to the sixth-ranked situation, design is separated from construction. Although the situations/interventions/ actions that complement H&S, namely optimum project period, design is complete when construction commences and design and construction are integrated relative to H&S, achieved rankings of fifth, seventh and eighth respectively, their II values are above the midpoint value of 2,0. The II value of prequalification of contractors on H&S, which is a critical 'upstream' action relative to H&S, is only 1,02. This

Table 1 Importance of various project parameters to respondents' practices

Parameter	Unsure	Response (%) Not ..... Very					II	Rank
		1	2	3	4	5		
Project quality	0,0	1,0	0,0	3,1	26,8	69,1	3,63	1
Public health and safety	0,0	2,1	3,2	12,8	21,3	60,6	3,35	2
Schedule (time)	0,0	1,0	0,0	15,5	38,1	45,4	3,27	3=
Cost	0,0	2,1	3,1	10,3	35,1	49,5	3,27	3=
Project health and safety	3,1	3,1	5,2	13,4	36,1	39,2	2,97	5

Table 2 Frequency at which practices consider/refer to H&S on various occasions

Occasion	Unsure	Response (%) Never	Rarely	Sometimes	Often	Always	II	Rank
Site meetings	0,0	0,0	2,1	12,4	35,1	50,5	3,34	1
Site inspections/discussions	0,0	1,0	1,0	13,4	41,2	43,3	3,25	2
Site handover	1,0	1,0	6,3	12,5	28,1	51,0	3,20	3
Preparing project documentation	0,0	1,0	4,1	18,6	33,0	43,3	3,13	4
Detailed design	0,0	2,1	13,5	24,0	31,3	29,2	2,72	5
Working drawings	1,0	1,0	18,6	22,7	33,0	23,7	2,58	6
Pre-tender meeting	1,0	4,2	20,8	18,8	30,2	25,0	2,49	7
Constructability reviews	2,1	2,1	17,5	24,7	37,1	16,5	2,44	8
Concept (design)	0,0	4,1	14,4	35,1	28,9	17,5	2,41	9
Client meetings	0,0	4,1	12,4	41,2	32,0	10,3	2,32	10
Design coordination meetings	0,0	3,1	17,5	41,2	25,8	12,4	2,27	11
Evaluating tenders	0,0	9,4	29,2	22,9	25,0	13,5	2,04	12
Deliberating project duration	4,1	9,3	25,8	29,9	26,8	4,1	1,82	13
Prequalifying contractors	3,2	13,7	28,4	20,0	26,3	8,4	1,81	14

Table 3 Frequency at which practices consider/refer to H&S relative to various design-related aspects

Aspect	Unsure	Response (%)					II	Rank
		Never	Rarely	Some-times	Often	Always		
Specification	1,0	3,1	8,2	8,2	35,1	44,3	3,07	1
Method of fixing	3,1	3,1	6,2	14,4	34,0	39,2	2,94	2
Design (general)	1,0	0,0	10,4	21,9	38,5	28,1	2,82	3
Details	1,0	4,2	14,6	19,8	33,3	27,1	2,63	4
Type of structural frame	10,4	8,3	8,3	15,6	19,8	37,5	2,49	5
Position of components	5,2	7,2	13,4	18,6	36,1	19,6	2,37	6
Content of material	5,2	7,2	9,3	32,0	25,8	20,6	2,33	7
Plan layout	6,2	7,2	11,3	22,7	35,1	17,5	2,32	8
Site location	4,1	9,3	17,5	18,6	27,8	22,7	2,29	9
Schedule	4,1	10,3	13,4	28,9	28,9	14,4	2,15	10
Elevations	7,2	9,3	18,6	19,6	28,9	16,5	2,10	11
Mass of materials	8,3	7,3	18,8	24,0	24,0	17,7	2,09	12
Edge of materials	8,2	8,2	15,5	32,0	22,7	13,4	2,01	13
Finishes	4,1	11,3	18,6	33,0	23,7	9,3	1,93	14
Surface area of materials	8,3	12,5	22,9	29,2	16,7	10,4	1,73	15
Texture of materials	9,3	11,3	25,8	29,9	14,4	9,3	1,66	16

Table 4 Frequency at which various situations that impact on H&S arise

Situation/state/action	Unsure	Response (%)					II	Rank
		Never	Rarely	Some-times	Often	Always		
Competitive tendering	0,0	0,0	2,1	9,4	42,7	45,8	3,32	1
Variation orders	1,0	0,0	4,2	21,9	46,9	26,0	2,96	2=
Drawings are revised	0,0	0,0	4,2	17,7	56,3	21,9	2,96	2=
Clients revise their requirements	1,0	0,0	12,5	18,8	56,3	11,5	2,67	4
Optimum project period	1,0	3,1	10,4	27,1	45,8	12,5	2,55	5
The design and construction processes are separated	1,0	2,1	21,9	25,0	42,7	7,3	2,32	6
Design is complete when construction commences	0,0	7,3	25,0	17,7	37,5	12,5	2,23	7
Design and construction are integrated relative to H&S	2,1	3,2	24,2	38,9	17,9	13,7	2,15	8
Pre-qualification of contractors on H&S	4,2	34,4	38,5	12,5	7,3	3,1	1,02	9

Table 5 Extent to which various aspects/actions could contribute to an improvement in H&S

Aspect/action	Un-sure	Response (%)					II	Rank
		Not ..... Very						
		1	2	3	4	5		
Project-specific plan for H&S	2,1	1,0	2,1	11,3	43,3	40,2	3,22	1
H&S programme	3,1	0,0	3,1	13,4	45,4	35,1	3,16	2
Quality management system (QMS)	3,1	0,0	3,1	17,5	46,4	29,9	3,06	3
Project-specific plan for quality	1,0	0,0	4,2	18,8	51,0	25,0	2,98	4
Pre-qualification of contractors on quality	0,0	0,0	2,1	24,7	48,5	24,7	2,96	5
Constructability reviews by engineering designers	1,0	0,0	6,2	19,6	57,7	15,5	2,83	6
Contract documentation	1,0	2,1	6,2	28,9	36,1	25,8	2,78	7
Client actions contributions	1,1	2,1	9,5	24,2	42,1	21,1	2,71	8
Contractor programming	0,0	1,0	8,3	29,2	45,8	15,6	2,67	9
Prioritisation consideration by engineering designers	3,1	6,2	4,1	25,8	47,4	13,4	2,60	10
Integration of design and construction in terms of H&S	2,1	6,2	6,2	30,9	43,3	11,3	2,48	11
Optimum project programme	5,2	4,2	11,5	32,3	34,4	12,5	2,42	12
Pre qualification of contractors on H&S	3,1	4,1	13,4	34,0	32,0	13,4	2,38	13
Environmental management system (EMS)	2,1	4,1	15,5	38,1	30,9	9,3	2,26	14
Choice of procurement system	8,4	11,6	16,8	34,7	18,9	9,5	1,98	15
Partnering	18,6	8,2	17,5	36,1	14,4	5,2	1,89	16

situation needs to be addressed by engineering designers.

Table 5 indicates the extent to which practices perceive various aspects/actions could contribute to an improvement in H&S performance in terms of percentages relative to a scale of minor to major. With the exception of choice of procurement system and partnering, all the II values are above the midpoint value of 2,0, which indicates all the aspects/actions can be deemed to be able to contribute to an improvement in H&S. The level of 'unsure' response relative to partnering is possibly attributable to a lack of knowledge and/or familiarity therewith. The II value of project specific plan for H&S and the concomitant ranking is significant, as international literature stresses the role of project specific plans in H&S performance, and 3,22 falls in the range $> 3,2 \leq 4,0$, which indicates that it can be deemed to be perceived to have between near major to major/major potential to contribute to an improvement in H&S. The level of affirmative response relative to the top three ranked aspects/actions is significant. It is also significant that two of the top three are solely design related and that the third aspect/action, project specific plan for H&S and quality requires designer and contractor input. Various authors support the perceived potential contribution by clients and contractor programming (Hinze 1997; Levitt & Samelson 1993). The fifth to seventh rankings achieved by QMS, prequalification of contractors on H&S and contract documentation, reflects the potential contribution expressed in literature (Levitt & Samelson 1993).

Table 6 Negative effect of inadequate H&S

Aspect	Yes response (%)
Productivity	68,0
Cost of construction	39,2
Environment	39,2
Client quality satisfaction	38,1
Project programme	37,1
Designer satisfaction	27,8
Don't know	9,3
None	3,1
Other	2,1

Table 6 indicates that productivity predominates among aspects in terms of the negative effect of inadequate or the lack of H&S. It is notable that between 37 % and 40 % identified cost of construction, environment, client quality satisfaction, project programme and designer satisfaction. It is also notable that 9,3 % did not know and 3,1 % identified none.

Respondents were asked to rate their knowledge of H&S on a scale of 1 (minimal) to 5 (substantial): 3,1 % identified minimal, 7,2 % less than average, 63,9 % average, 20,6 % more than average, and 5,2 % substantial. Although the resultant

II of 2,18 is only marginally higher than the midpoint value of 2,0, the fact that it is higher indicates that knowledge of H&S can be deemed to exist.

Table 7 Means by which H&S knowledge was acquired

Means	Yes response (%)
Experience	90,7
Magazine articles	30,9
Workshops	27,8
Practice notes	16,5
Tertiary education	15,5
Journal papers	12,4
Conference papers	11,3
Postgraduate qualifications	7,2
Other	6,2
CPD seminars	3,1

Experience predominates in terms of the means by which respondents acquired their H&S knowledge (table 7). However, given that certain experiences can result in disabling or fatal injuries, experience is not the recommended means by which to acquire H&S knowledge. The next most common means are magazine articles and workshops, which were only identified by between 27 % and 31 % of respondents. Given the role of tertiary education (Smallwood 2002), it is significant that this means was only identified by 15,5 % of respondents. Although journal and conference papers were only identified by between 11 % and 13 % of respondents, relative to the other means and along with magazine articles, they do contribute substantially to the acquisition of H&S knowledge. The level of response relative to practice notes, postgraduate qualifications, and CPD seminars indicates their potential for increased contribution.

Approximately 60 % of respondents stated that H&S should be included in a component of a subject such as construction management at technikons and universities (table 8). It is notable that 25 % and 15,6 % respectively stated that there should be a separate subject H&S.

CONCLUSIONS

The importance of H&S and other project parameters to engineering designers

With the exception of public safety, the descriptive survey reflects the findings of literature, namely that quality, schedule and cost are the 'most important' parameters. The high ranking achieved by public safety is probably attributable to engineering designers' liability for design. Although project H&S is perceived to be important, it is concluded that engineering designers consider the traditional project parameters (cost, quality and schedule) and public H&S more important than project H&S.

Table 8 Extent to which H&S should be addressed in technikon and university engineering designer programmes

Institution	A subject 'H&S'	Included in a component of a subject, eg construction management	Included in a range of subjects	Not at all
Technikon	25,0	60,4	18,8	0,0
University	15,6	63,5	24,0	0,0

The extent to which construction H&S is addressed in tertiary education programmes is inadequate and needs to be addressed.

The frequency at which engineering designers consider and/or refer to H&S during the design and construction phases

It can be concluded that H&S can be deemed to be considered and/or referred to by engineering designers on most occasions during design and construction. However, the attention is more prevalent during construction than during design and procurement.

The frequency at which engineering designers consider and/or refer to H&S relative to various design-related activities

It can be concluded that H&S can be deemed to be considered and/or referred to by engineering designers during design-related activities.

The frequency at which various procurement-related situations or interventions which affect H&S are encountered or taken by engineering designers respectively

It can be generally concluded that situations or interventions which negatively affect H&S are encountered or taken more frequently than those that positively affect H&S – the former being 'competitive tendering', 'variation orders', 'drawings are revised', and 'clients revise their requirements', and the latter being 'design is complete when construction commences', 'design and construction are integrated relative to H&S', and 'prequalification of contractors'.

The extent to which engineers perceive aspects or actions can contribute to an improvement in H&S performance

It can generally be concluded that various aspects and actions related to design, procurement and construction have the potential to contribute to an improvement in H&S. The top four ranked aspects or actions clearly indicate the necessity for project specific plans, programmes and management systems.

The perceived impact of inadequate or the lack of H&S on other project parameters

Although engineering designers appreciate the extent to which inadequate or the lack of H&S negatively affects productivity, they do not do so relative to the other project parameters.

RECOMMENDATIONS

H&S should be afforded status equal to that afforded the traditional project parameters / performance measures of cost, quality and schedule (time), by clients, designers, PMs and contractors.

Engineering programmes should include H&S education.

Engineering designers should consider or refer to H&S more frequently during the upstream phases of design, namely concept design, constructability reviews, and design coordination meetings. A similar recommendation applies relative to evaluating tenders, deliberating project duration, and prequalifying contractors on H&S.

Relative to design-related aspects, engineering designers should consider or refer to H&S more frequently relative to a number of aspects that are considered or referred to between rarely to sometimes/sometimes: position of components; content of material; plan layout; site location; schedule; elevations; mass of materials; edge of materials; finishes; surface area of materials, and texture of materials.

Engineering designers should endeavour to

- integrate design and construction
- realise an optimum client brief
- finalise design before construction commences
- discourage client changes
- prequalify contractors on H&S and quality
- include a specific mention of, and a financial allowance for, H&S in contract documentation
- avoid competitive tendering, and
- realise the implementation of QMSs in design and construction

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