Get It Right Initiative

Improving value by eliminating error

Research Report

Revision 3 – April 2016

Expedition R&D was commissioned by the Get It Right Initiative to undertake this research project. Funding was provided by leading contractors and the CITB Growth and Innovation fund.

Arrangement of the Report

The report is arranged in four volumes:

- A Call to Action
- Strategy for Change
- Research Report
- Literature Review

This document forms the Research Report.

Contents

Objectives of the Get It Right Initiative:

- To generate a significant change in the efficiency of the UK construction industry through reducing the amount of errors made in construction.
- To undertake research to identify, evaluate and prioritise the principal systemic errors in the construction process.
- To develop a strategy to address these errors and in particular to address deficiencies in skills.
- To develop new training products and processes to address the skills deficiencies (To be covered in a later phase).

1. Organisation

The Research Team

This research team for this phase of the Get It Right Initiative was led by Ed McCann and Tom Barton.

Ed McCann is a Director of Expedition Engineering; he is an innovative and creative designer. Ed is a Fellow and Trustee of the ICE and chairs their National Best Practice Panel. Ed is also a Royal Academy of Engineering Visiting Professor of Innovation at University College London and Strathclyde University.

Tom Barton is a Fellow of the Institution of Civil Engineers. He has had over 40 years' experience working firstly with John Mowlem and Company and for the last 18 years with Sir Robert McAlpine Ltd working on some significant projects mainly in the UK but also overseas. Tom was the Deputy Regional Manager (London and South East) for Sir Robert McAlpine, and before that a Director of John Mowlem & Co. plc.

Their principal assistant was Bruce Martin, Associate Director, Expedition Engineering, MIStructE.

The literature review was completed by Kell Jones, Research Engineer, Chartered Accountant and Architectural Planner, Expedition Engineering and University College London.

The Steering Group

This phase of the Get It Right Initiative has been guided by a Steering Group which includes:

Malcolm Corlett	Head of Civil Engineering	BAM Nuttall
David Anderson	Head of Business Process & Quality	BAM Nuttall
Damian Leydon	Operations Director	Berkeley Group
Simon Taylor	Group HS&E Director	Byrne Brothers
Zara Lamont	Performance Improvement Director	Carillion
Howard Tinkler	Quality and Compliance Director	Carillion
Paul Cannon	Commercial Manager	Carillion
Clive Loosemore	Director	Costain
Emer Murnaghan	Head of Business Improvement	GRAHAM Construction
John Price	Managing Director	Keltbray
John Podmore	Business Improvement Manager	One Alliance
David Ansell	Associate Director	Prater
Cliff Smith	Business Improvement Manager	Sir Robert McAlpine

Jim Neill	Company Chief Engineer	Sir Robert McAlpine
Ian Kirkaldy	Chief Engineer	Southern Water
Barrie Nightingale	Director	T. Clarke
Emma McNab	Business Excellence Manager	Taylor Woodrow
John Shannon	Programme Director	Wates

Additional oversight has been provided by Hayley Monksfield, David Plummer and Richard Bayliss of the CITB

Contributors

The following organisations have contributed to this phase of the Get It Right Initiative:

Alinea Consulting

Anglian Water

BAM Nuttall

Berkeley St James Group

Byrne Group

Carillion

CITB

Costain

GRAHAM Construction

Imtech

Keltbray

Prater Limited, Linder UK Group

Qatar National Bank (QNB)

Scotch Partners

Sir Robert MacAlpine

Southern Water

Stanhope

Taylor Woodrow

Wates

We are very grateful for all of the contributions of time and finance.

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Letters of support for the Get It Right Initiative have been received from:

Civil Engineering Contractors Association (CECA)

Construct – Concrete Structures Group

Severfield (UK) Ltd

The Department for Business Innovation & Skills

The Institution of Civil Engineers

2. Acknowledgements

We held five productive meetings with the steering group. In addition we met on an individual basis with each of the companies represented on the steering group and a number of other companies as identified in section 4.2 below. All of these meetings were very open and very instructive. We would like to thank all of the companies and people for all of their time and input.

Many other people have given their time and knowledge, not least the 143 construction industry professionals who anonymously responded to an online questionnaire which was circulated by the Get It Right research team.

3. Terminology

Across the construction industry there is wide variation in the language used to discuss errors / defects / snags / rework requirements / non-conformances etc.

After investigation and discussion with the Steering Group we have adopted the following definitions for the purpose of the Get It Right initiative:

- an **error** is any action or inaction which results in a requirement for re-work, a requirement for extra work, or produces a defect, and
- a **defect** is any failure to meet the project requirements at a handover.

A handover may be from one contractor to another contractor on completion of a package, or a handover may be from a Tier 1 Contractor to a Client on completion of a project.

Note that the results of errors which are resolved before a handover are not considered defects.

The labour, materials, plant and other resources used in correcting an error are **direct costs.**

The effect on following works and the costs to other parties are **indirect costs**. For example if the steel frame was completed late due to correcting an error the cladding contractor would have costs overcoming delays. Regardless of who picks up the contractual liability there is still a cost to the project.

A **latent defect** remains in place after the project has been accepted by the client and any 'defects liability period' has passed.

Unrecorded process waste includes errors which occur, are identified and are corrected without being recorded - for example reinforcement may be refixed without costs being recorded. **Unrecorded process waste** also includes errors which are not corrected but which do not compromise the end performance of the project - for example concrete used as backfill in place of lower grade fill.

4. Methodology

We used the Grounded Theory Method to collect and analyse information on error in the UK construction industry, the causes of error and the methods used for avoiding error. The analysis of the data collected identified the areas of work in which error is financially most significant, the financially most significant causes of error and the most effective methods for avoiding error and minimising the consequences of error.

We used the Delphi Method to rank the results of the Grounded Theory Method analysis and to assess the relative financial impact of:

- The direct costs of error,
- The indirect costs of error,
- Latent defects and
- Unrecorded process waste.

The Delphi Method was also used to identify the most effective methods of reducing the financial impact of error in the construction industry.

An anonymous online survey of construction industry professionals was used to assess the results of the ranking analyses completed using the Delphi Method. If there were large divergences between the rankings arising from the Delphi Method analysis and the online survey this might indicate that the Delphi Method results are not representative of the view of the wider industry.

A Literature Review was completed and the results are compared with the findings of the Grounded Theory and the Delphi Method analyses. The Literature Review also provided an approximate value of the direct costs of error as a percentage of the total cost of construction. This figure was used in combination with the results of the Delphi Method analysis to estimate the total financial cost of error in the UK construction industry.

The results of the above were used to inform development of a strategy to reduce error in the UK construction industry and to address deficiencies in skills within the UK construction industry.

The Steering Group provided guidance throughout this phase of the Get It Right Initiative.

4.1. The steering group

The steering group met five times. Its key role was to act as a sounding board to the results of the research at each stage and to inform the next stage of research. The steering group members were the participants in the Delphi Method analyses.

The steering group discussions were conducted on the basis no information would be published that would allow any opinion, error, defect, error incidence rate or defect incidence rate to be linked to a particular company or individual.

The members of the Steering Group are listed in Section 1 of this report.

4.2. Collection and Analysis of Information using the Grounded Theory Method

We have adopted a version of the “Grounded Theory” research method for this project. Rather than a classical research approach where you postulate a hypothesis and then attempt to prove or disprove it, the Grounded Theory Method sets questions and then attempts through investigation to identify the most plausible answers. Our research questions were:

- What are the principal systemic errors in the UK construction industry?
- What are the causes of error in the UK construction industry?
- What are methods used to capture information about the financial cost of error in the UK construction industry?
- What are the most effective methods for avoiding error and minimising the consequences of error?

We used three methods to collect data:

- A workshop with the steering group,
- Structured interviews with the members of the steering group and a number of other companies in the sector;
- Collection of quantitative data relating to individual error occurrences. This included:
    - A descriptions of each of the errors,
    - A description of the causes of each of the error occurrences,
    - An assessment of the financial cost of each of the error occurrences.

  This information was collected from the participants in the structured interviews.

The data was analysed by the Get It Right Initiative team as it was collected. The emerging findings were discussed in steering group meetings to draw on the expertise of the Steering Group members for the identification of theories.

The structured interviews were completed and the quantitative data was collected on the basis that no information would be published that would allow any opinion, error, defect, error incidence rate or defect incidence rate to be linked to a particular company or individual.

The structured interviews were conducted with the following nineteen companies:

Alinea Consulting (Cost Consultant)

Anglian Water (Client)

BAM Nuttall (Main Contractor)

Berkeley Group (Main Contractor)

Byrne Group (Trade Contractor)

Carillion (Main Contractor)

Costain (Main Contractor)

GRAHAM Construction (Main Contractor)

Keltbray (Trade Contractor)

Prater Limited - Lindner UK Group (Trade Contractor)

Qatar National Bank (QNB) (Client)

Scotch Partners (Designer)

Sir Robert McAlpine (Main Contractor)

Southern Water (Client)

Stanhope (Client)

Taylor Woodrow (Main Contractor)

Wates (Main Contractor)

4.3. Analysis of the Grounded Theory results using the Delphi Method

The Delphi Method is a system for achieving well considered consensus among experts. In the Delphi Method a group of experts anonymously reply to questionnaires and subsequently receive feedback of the 'group response'. After the feedback the experts again anonymously reply to questionnaires. The process is repeated until a predefined stop criterion is achieved. Thus, experts are encouraged to revise their earlier answers in the light of the replies of other members of their panel. It is intended that during this process the range of the answers will decrease and the group will converge towards the "correct" answer.

We used the Delphi Method to rank the results of the Grounded Theory Method analysis and to assess the relative financial impact of:

- The direct costs of error,
- The indirect costs of error,
- Latent defects and
- Unrecorded process waste.

The Delphi Method was also used to identify the most effective methods of reducing the financial impact of error in the construction industry.

The panel of experts was made up of the following members of the Steering Group:

David Anderson	Head of Business Process & Quality	BAM Nuttall
Damian Leydon	Operations Director	Berkeley Group
Howard Tinkler	Quality & Compliance Director	Carillion
Paul Cannon	Commercial Manager	Carillion
Clive Loosemore	Project Director	Costain
David Ansell	Associate Director	Prater
Ian Kirkaldy	Chief Engineer	Southern Water
Barrie Nightingale	Director	T. Clarke
Emma McNab	Business Excellence Manager	Taylor Woodrow
John Shannon	Programme Director	Wates

Members of the Research Team acted as the facilitators.

The experts anonymously answered four questions:

- The first question entailed ranking the areas of work which had been identified by the Grounded Theory Method as being the areas where error has a significant financial impact. The experts were asked to rank the areas of work according to their assessment of the financial impact of error in each of the areas of work.
- The second question required the experts to rank the root causes of error which had been identified by the Grounded Theory Method as having a significant financial impact. The experts were asked to rank the root causes of error according to their assessment of the financial impact of each of the root causes of error.
- The third question asked the experts to assess the relative financial impact of: the direct costs of error, the indirect costs of error, latent defects and unrecorded process waste.
- In the fourth question the experts were asked first to assess how spend should be distributed across the areas of work to achieve the maximum reduction in the cost of error, and second to assess how spend should be allocated within each of the areas of work.

Each of the questions also asked the expert to identify:

- Whether the organisation that the expert works for is primarily a trade contractor, a main contractor, a designer or a client.
- Whether the work of the organisation that the expert works for relates primarily to Civil Engineering or Buildings.

On completion of the first round of answers to the four questions the group response was fed back to the experts. After a facilitated discussion of the group response the experts anonymously answered the same four questions.

Two rounds of answers to the questions was the predetermined stop criterion.

4.4. Assessment of the results of the ranking analysis completed using the Delphi Method

We used an anonymous online survey of construction industry professionals to assess the results of the ranking analyses completed using the Delphi Method. If there were large divergences between the rankings arising from the Delphi Method analysis and the online survey this might indicate that the Delphi Method results are not representative of the view of the wider industry.

A link to the questionnaire was circulated by members of the Steering Group to the contractors in their supply chain. A link to the questionnaire was also circulated by the Civil Engineering Contractors Association (CECA) to their members.

All questions were answered anonymously.

The survey first asked respondents to identify:

- Whether the organisation that the respondent works for is primarily a trade contractor, a main contractor, a designer or a client.

- Whether the work of the organisation that the respondent works for relates primarily to Civil Engineering or Buildings.

The respondents were then asked two questions

Q1. The first question entailed ranking the areas of work which had been identified by the Grounded Theory Method as being the areas where error has a significant financial impact. The respondents were asked to rank the areas of work according to their assessment of the financial impact of error in each of the areas of work.

Q2. The second question required the respondents to rank the root causes of error which had been identified by the Grounded Theory Method as having a significant financial impact. The respondents were asked to rank the root causes of error according to their assessment of the financial impact of each of the root causes of error.

After completing the first and second questions respondents were invited to add discursive comment. The principal purpose of this section of the survey was to enable respondents to make comment if they felt that the items identified by the Grounded Theory Method failed to include financially significant factors.

The pages from the online questionnaire are included in Appendix A.

4.5. Literature Review

A literature review was completed in two phases.

The purpose of the first phase of the literature review was to provide an awareness of the work which has been completed by others and ensure that the research team did not repeat work completed by others. The first phase of the literature review informed the initial discussions of the Steering Group in which the strategy for this phase of the Get It Right Initiative was agreed.

The second phase of the literature review was more detailed. The second phase of the literature review was used:

1. As a comparator for the results of the Delphi Method analysis. If there were large discrepancies between the rankings arising from the Delphi Method analysis and the results of previous studies this might indicate that the Delphi Method results are not representative of the view of the wider industry.
2. To inform the development of a strategy to reduce error in the UK construction industry and to address deficiencies in skills within the UK construction industry.
3. The Literature Review also provided an approximate value of the direct costs of error as a percentage of the total cost of construction. This figure was used in combination with the results of the Delphi Method analysis to estimate the total financial cost of error in the UK construction industry.

The second phase of the literature review was not available until after the experts had answered the Delphi Method questions thus avoiding introducing concepts from the literature into the experts' answers.

The literature review is included in Appendix B.

5. Results

5.1. Collection and Analysis of Information using the Grounded Theory Method

As described above, we used three methods to collect data:

- A workshop with the Steering Group,
- Structured Interviews with the members of the steering group and a number of other companies in the sector;
- Collection of quantitative data relating to individual error occurrences. This included:
  - A descriptions of each of the errors,
  - A description of the causes of each of the error occurrences,
  - An assessment of the financial cost of each of the error occurrences.

  This information was collected from the participants in the structured interviews.

The Steering Group workshop and the Structured Interviews were very effective and provided useful data.

The collection of quantitative data was less effective. Few of the organisations that we interviewed had detailed quantitative data relating to errors. Where information was available the financial details generally related solely to the direct cost of error to the organisation being interviewed, rarely was information available on the cost (direct or indirect) to other parties. The quantitative data that was available all related solely to the direct cost of recorded error.

Although the information relating to individual error occurrences was limited, we were able to use the data that was provided about turnover and the reported total direct cost of error to individual organisations to review estimates of the total direct cost of recorded error.

Tier 1 Contractors have an overview of the construction process and provided useful information about the incidence and impact of error across the different trades.

The initial cost of errors is incurred by the Tier 2 Contractors and this cost is often invisible both to Tier 1 Contractors and to end Clients.

5.1.1. Areas of work in which errors occur with greatest frequency

The limited availability of quantitative data has made it impossible for us to identify the errors that have the largest financial impact in the UK construction industry.

We have been able to identify the areas of work in which errors occur with greatest frequency, as reported by our study group. The ranking in the table below is by the reported frequency of occurrence of error. The ranking does not necessarily reflect the economic significance, as some errors whilst frequent may have low cost impact.

1. In Situ Concrete
2. Drainage
3. Piling
4. Mechanical Systems
5. Finishes
6. Damage to completed works
7. Facades / Cladding
8. Electrical Systems
9. Roads and Pavements
10. Roofing
11. Controls / BMS
12. Timber
13. Setting out
14. Steelwork coatings
15. Temporary works
16. External works
17. Structural steel
18. Lifts
19. Cold bridging
20. Damage to live services
21. Underground waterproofing
22. Utility connections
23. Tunnels
24. Masonry
25. Earthworks
26. Basement Waterproofing

Timber errors were reported have a relatively higher frequency but lower financial impact.

Errors in setting out were reported to be low frequency but high cost.

Some respondents reported a very high rate of error in steel coatings with a high knock on effect on following trades.

Although reported to be areas of work in which there is a lower frequency of occurrence of errors "Underground Waterproofing" and “Basement Waterproofing” were reported to be areas of work in which the financial impact of error is significant.

5.1.2. The root causes of error

The list below sets out the root causes of error that were reported within our study group. The ranking here is by frequency of reporting. The ranking does not necessarily reflect the economic significance as some of the root causes, whilst frequent, may have low cost impact.

It was reported that although the errors and defects vary between trades, the causes of the defects are often the same.

1. Management and Planning
2. Communications
3. Workmanship
4. Design
5. Materials
6. Interface Design and Management
7. Commercial Pressures
8. Late changes
9. Information overload
10. Inadequate training
11. Setting out
12. Fabrication
13. Lack of focus on quality
14. Designers having a poor understanding of details
15. Design fees
16. Late surveys and investigations
17. Programme
18. Time
19. Core skills
20. Outside of core geographical range of work
21. Motivation

The notes below provide statements that summarise the most frequently stated opinions.

Management and Planning

Lack of planning at all levels (including operatives) is a key cause of error.

There was a view that planning skills are not as good as necessary particularly when planning involves co-ordination across trades.

There are often valid reasons why work does not proceed in accordance with the plan. Once the works start to deviate from the plan matters quickly go from bad to worse.

There is often insufficient supervision of site works. Supervisors are often insufficiently briefed or trained on how to supervise the trades and techniques on progress on that day: The same person may be involved in supervising a wide range of different trades.

Scarce resource for supervision of site works is often poorly allocated to areas where the most work is visible, rather than to the areas where there is the greatest risk of error. Works that are difficult to access and inspect often suffer from a lack of site supervision and inspection.

There is often insufficient checking as the work progresses; the consequence is that the financial cost of errors is increased.

Poorly aligned package scope and trade contractor skills can result in error. This is particularly the case when specialist trade contractors are required to manage further subcontractors.

There is a general determination to get it done so that subsequent works can proceed. Sometimes it appears easier just to do something than it is to take the time to work out what is the right thing to do. All of the study group have talked about problems arising because of a failure to make time to plan or to find out how the work should be done.

As an industry we have a real "can do" approach. We are instinctively keen to get on with each stage of a project and often proceed before the work has been fully planned. This "can do" approach is present across the industry, ranging from a tradesman who starts work before he or she has fully thought through what they should be doing to construction work started before the design is complete (thereby risking design changes with all the costs and disruption that can incur).

We never have time to get it right. We always have time to put it right.

It is sometimes difficult for staff to ask for help. There is a lack of awareness that one person cannot be an expert about everything.

Communication

Communication between all parties was reported to be a key cause of error. This included all forms of communications: written, drawn and verbal.

Communication 'up the chain' can be a particular problem:

- Site operatives sometimes lack the confidence or motivation to ask questions or make comment. Sometimes site operatives are insufficiently heard.
- Site culture or relationships sometimes make it difficult for suppliers to discuss in good time the possibility of a missed delivery date.

Many examples were given of people not being able to express uncertainty or ignorance to their superiors or workmates.

Task Briefings sometimes concentrate on the safe way of doing the work and fail to address the technical requirements.

Documents, particularly specifications, are often too long and contain much irrelevant information. Irrelevant information is often left in because the person preparing the document lacked the experience to know what is unnecessary – or else information is left in "just in case" which makes it difficult to identify the information that is relevant.

Some respondents were sceptical that BIM provides real benefits.

There is a lot of emphasis in method statements as to how to do the work safely but there is rather less so on how to do the work without error.

Workmanship

It was widely reported that errors in workmanship are only rarely a result of a lack of skill on the part of the site operative.

Workmanship and operative technical ability are not generally seen as one of the principal causes of error, although there are isolated cases of poor workmanship or technical ability that do result in significant error. For example, it is not generally felt that errors in brickwork arise because bricklayers are not capable of mixing mortar and laying bricks, rather that for one reason or another they do not do what they are capable of doing consistently enough.

From the discussions it was understood that the errors assigned to 'workmanship' relate generally to failures in planning the task rather than to technical competence.

A view that has come up repeatedly is that people lack sufficient contextual knowledge to be able to complete their work effectively. In particular a lack of proper understanding of the roles undertaken and challenges faced by others involved in the construction process often results in inappropriate decisions or actions being taken. The study group have an almost endless supply of examples where errors have arisen as a result of this mutual ignorance. A few examples are given below as illustrations of situations that appear to be commonplace within the industry:

- In ignorance a designer unnecessarily specifies fixings from a manufacturer's catalogue that are not stock items, resulting in procurement delays and consequent changes to planned construction sequence.
- The procurement team substitute the specified 200m of 150mm diameter clay pipe with 200mm of 150mm diameter plastic pipe (to reduce cost) without understanding that the ground on the site in question has relatively high levels of hydrocarbon contamination and that the plastic is not suitable, with the outcome that the Contractor has to dig up and replace the entire drain run.
- The bricklayer uses 10.5N 100mm blocks to build the non-load bearing partitions which only require 3.6N blocks not realising that they are a relatively long lead item specifically intended for the load bearing walls nearby. The outcome in this case was delay and additional costs incurred to replace the 10.5N blocks.

Interestingly in none of these examples did the error result in a defect, although all were relatively costly for the projects concerned.

Design

Design Changes (late or otherwise) were identified as a key cause of error.

Designs, and detailing in particular, are sometimes unsuitable.

Materials

It was reported that errors arising from problems with materials were often a result of late changes.

It was reported that late changes in materials are often made by people who do not understand the effect of the change being made – often the person making the change is unaware that they have 'made a change'. For example it was reported that buyers sometimes order alternatives without being aware that there are real technical differences between the more expensive product specified and the cheaper alternative.

Materials are sometimes changed because the item that was specified cannot be supplied in the time that is available.

Interface Design and Management

It was reported that, as well as the design and coordination of interfaces, tier 2 Contractors are often put under pressure by late handover from previous trades which contributes to errors.

It was reported that when a tier 2 contractor performs well they may be inundated with work without adequate consideration of capacity and that this does result in errors.

Several of the study group have identified poor management and planning associated with interfaces between different systems and trades as being a particular problem.

Setting out

Although this was reported to be a cause of error, we consider incorrect setting out to be an error in itself with the costs arising being an indirect cost of the setting out error.

Fabrication

Although this was reported to be a cause of error, we consider incorrect fabrication to be an error in itself with the costs arising being an indirect cost of the setting out error.

5.1.3. Capturing the cost of error

There is significant variation in whether and how companies collect and report the costs of errors and defects. Most companies recognise that there is a cost issue with errors but it appears that none is clear as to the full extent of those costs.

Few of the organisations that we interviewed had detailed quantitative data relating to errors. Where information was available the financial details generally related solely to the direct cost of error to the organisation being interviewed, rarely was information available on the cost (direct or indirect) to other parties. All of the systems that we saw only capture the direct cost of error, and do that only partially.

None of the organisations that we interviewed was able to provide data relating to indirect costs or unrecorded process waste, although some participants were willing to express a view.

The direct cost of errors which result in defects
(a **defect** is any failure to meet the project requirements at a handover)

- Where Contractors do record the results of error the records generally relate to failures to meet the project requirements at handovers – “defects”.
- Some of the organisations that we interviewed have detailed records of pre-completion defects while others have details of post completion defects. None of the organisations that we interviewed had information available on both. It was reported in some organisations that the board was principally interested in the cost of latent defects since these were perceived to affect ‘the bottom line’.
- Several organisations had systems in place which did not focus on cost of error, but instead recorded the number of defects remaining on completion or, in different organisations, the number of defects reported and resolved during the construction process. None recorded everything.
- There was generally more formalisation of the error recording systems in organisations with a larger proportion of large publically funded projects.
- Most contractors acknowledge that the recording systems which they use do not allow them to capture the cost of error in some areas. For example some Tier 1 Contractors reported that the costs of M&E defects are not disclosed by Tier 2 Contractors.
- There was insufficient standardisation in the recording of error in the study group for us to use the detailed quantitative data which we did receive from a number of the study group to make a meaningful assessment of the cost of individual error types.
- The bulk of the direct cost of error relates to materials, plant and labour costs. These costs are carried by the Tier 2 Contractors. We were not able to obtain good data on the direct cost of error to Tier 2 Contractors.
- The direct cost of error to Tier 1 Contractors is largely associated with the additional management associated with rectifying errors. A review of the data from the Tier 1 Contractors suggests that the direct cost of managing errors which result in defects is in the range of 0.5% – 1.0% of project costs. Not surprisingly the total direct cost of errors which result in defects to Tier 1 Contractors with significant direct labour costs is reported to be substantially above 1.0%.
- Tier 1 Contactor costs for managing construction projects are generally in the order of 10% - 20% of the total cost of construction (depending on sector and project type). Therefore the reported direct cost of errors which result in defects to Tier 1 Contractors falls in the range 2.5% (0.5% / 20%) to 10% (1% / 10%) and is probably typically around 5% of turnover.

The direct cost of errors which are resolved before a handover – “unrecorded process waste”

- Very few Contractors record errors and the associated rework and extra work costs that are incurred before handovers. The direct costs of errors which are resolved before a handover are very rarely recorded.
- Most of the direct costs of errors which are resolved before a handover are incurred by Tier 2 Contractors and below.
- It is likely that only a relatively small proportion of the total direct cost of error arises from errors which result in defects. The majority of the direct cost of error is understood to arise from errors which are resolved before a handover and which are not recorded as defects.
- Therefore the majority of the direct cost of error is, in effect, experienced as “process waste” at Tier 2 and below. We were not able to obtain sufficient quantitative data relating to unrecorded process waste to report a cross industry figure.
- When working with the NEC form of contract Tier 1 Contractors are sometimes rewarded if “Non-Conformances” amount to less than 2% of the contract value. In these cases the relevant “Non-Conformances” are items identified at handover by the Client’s Representative. We have been informed that the results of the majority of errors are usually corrected earlier, after having been identified during inspection by the Tier 2 Contractor or the Tier 1 Contractor. This indicates that the direct cost of error is generally substantially greater than 2% of the project cost.

The indirect cost of errors

- Generally Contractors were not able to provide an estimate of the indirect cost of error. One respondent estimated the indirect cost of error to the organisation to amount to an uplift of around 40% on the direct cost of error.

The total cost of errors

- No Contractors were able to provide an estimate of the total cost of error.
- All respondents agreed that the cost of error was substantially greater than the recorded cost. Few were able to provide an informed estimate of the total cost of error.
- Respondents told us that they believe the cost of error to Tier 2 Contractors in some trades to be between 20% and 25% of turnover. The respondents were not able to provide evidence to support these statements.
- Based on the discussion above it appears highly probable that the total cost of error in construction is considerably greater than 10% of the total cost of construction.
- Tier 1 Contractors have very little understanding of the true cost of error which is borne by their supply team.
- It appears perhaps not surprising that Clients are largely unaware of the amount of error embedded in the construction process or the consequent costs to them of these errors.
- There is some evidence to suggest that whilst the initial costs associated with errors occur in Tier 2 and below, the root causes may sit outside their control.

5.1.4. Methods used for avoiding error and minimising the consequences of error

Our research has also identified that most Contractors have a quality management system which is, in part, intended to reduce error and the associated financial impact. Several different theoretical frameworks have been used as a basis for these quality management systems and there does not appear to be an agreed industry standard.

Although different Contractors use different systems, the analysis demonstrates that adoption of systems designed to reduce error can deliver substantial financial savings.

In general Contractors that focus on large public sector projects have a more developed system for recording and assessing the results of error. Contractors working on smaller private sector projects are, in general, likely to use a less developed system or to have no formal system in place.

A number of companies have some excellent methods for eliminating error. These included quality circles, encouraging feedback from the workforce, benchmarks, use of mock ups and prototypes, encouraging people to stand back and think, encouraging people to ask when they are not sure, and quality risk assessments. The best examples of Good Practice come from those companies that have effective senior leadership interest in quality and that build an effective culture.

Among the people that we interviewed there is a strong school of thought that if you get the culture right everything else falls into place, including a reduction in the occurrence of error. It was emphasised that leadership is critical to definition of the culture of an organisation.

A demonstrated interest in quality by a Company's Board has a positive effect on reducing defects, markedly more so than a market approach which assumes that defects will be eliminated by focussing on costs.

Sites which adopt practices which result in high quality with few defects are generally safe sites almost certainly because there is good management.

It was reported that fewer errors occur on projects where the Client has put in systems to monitor quality.

It was also reported that there are fewer errors on projects where Clients demonstrate an interest in quality.

Independent checks completed by an external audit organisation were reported to be an effective means of reducing error.

5.2. Analysis of the Grounded Theory results using the Delphi Method

We used the Delphi Method to rank the results of the Grounded Theory Method analysis and to assess the relative financial impact of:

- The direct costs of error,
- The indirect costs of error,
- Latent defects and
- Unrecorded process waste.

The Delphi Method was also used to identify the most effective methods of reducing the financial impact of error in the construction industry.

The results of the analysis using the Delphi Method are summarised below. The changes in the results between the first and second round of the Delphi Method analysis were small.

5.2.1. Ranking of the areas of work according to the financial impact of error

The analysis using the Grounded Theory Method provided us with a list of the areas of work in which errors occur with greatest frequency, as reported by our study group. The ranking does not necessarily reflect the economic significance, as some errors whilst frequent may have low cost impact. There was some overlap between the categories with resulted from the Grounded Theory Method.

For the Delphi Method analysis we required a concise list of the areas of work. The table below summaries the consolidation of the categories and the amended category titles which were adopted for the Delphi Method analysis.

Results of the analysis using the Grounded Theory Method		**Categories taken forward for analysis using the Delphi Method to identify the areas of work in which error has the most significant financial impact.**	
Areas of work in which errors occur with greatest frequency, as reported by our study group.	Comments	Consolidated categories for analysis using the Delphi Method	Category titles as used in the analysis using the Delphi Method
1. In Situ Concrete		1. In Situ Concrete	Concrete Works
2. Drainage		2. Drainage	Drainage
3. Piling		3. Piling	Piling
4. Mechanical Systems		4. Mechanical Systems 11. Controls / BMS	Mechanical Systems (including BMS)
5. Finishes		5. Finishes	Finishes
6. Damage to completed works		6. Damage to completed works	Damage to completed works
7. Facades / Cladding		7. Facades / Cladding	Facades / Cladding
8. Electrical Systems		8. Electrical Systems	Electrical Systems
9. Roads and Pavements		9. Roads and Pavements	Roads and Pavements
10. Roofing		10. Roofing	Roofing
11. Controls / BMS	This category was combined with Mechanical Systems to form a single category for the analysis using the Delphi Method		
12. Timber	See note A.		
13. Setting out	Errors in setting out were reported to be low frequency but high cost	13. Setting out	Setting Out
14. Steelwork coatings	Some respondents reported a very high rate of error in steel coatings with a high knock on effect on following trades	14. Steelwork coatings	Steelwork coatings
15. Temporary works	See note B.		

Results of the analysis using the Grounded Theory Method		Categories taken forward for analysis using the Delphi Method to identify the areas of work in which error has the most significant financial impact.	
Areas of work in which errors occur with greatest frequency, as reported by our study group.	Comments	Consolidated categories for analysis using the Delphi Method	Category titles as used in the analysis using the Delphi Method
16. External works	See note B.		
17. Structural steel	See note B.		
18. Lifts	See note B.		
19. Cold bridging	See note B.		
20. Damage to live services	See note B.		
21. Underground waterproofing	See note C.	21. Underground waterproofing 26. Basement waterproofing	Basement Waterproofing
22. Utility connections	See note B.		
23. Tunnels	See note B.		
24. Masonry	See note B.		
25. Earthworks	See note B.		
26. Basement waterproofing	See note C.		

Notes:

A. The purpose of the analysis using the Delphi Method was to identify the areas of work in which error has the most significant financial impact. Although reported to have a high frequency, timber errors were also reported have a low financial impact. To allow the experts to focus on the key issues this category was therefore omitted from the analysis using the Delphi Method.

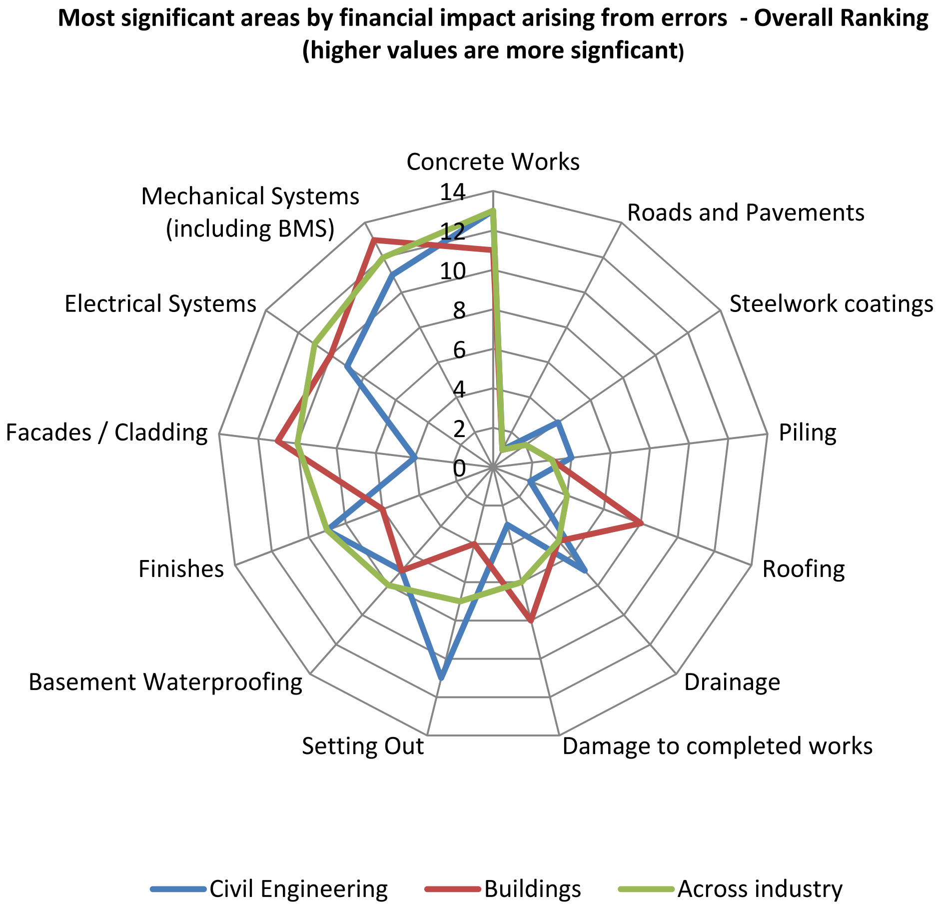
B. The purpose of the analysis using the Delphi Method was to identify the areas of work in which error has the most significant financial impact. Following the structured interviews it was understood that these areas of work in which errors occur at lower frequency were not the areas of work in which the financial impact of error was most significant. To allow the experts to focus on the key issues these categories were therefore omitted from the analysis using the Delphi Method.

C. Although reported to be areas in which there is a lower frequency of occurrence "Basement Waterproofing" and "Underground Waterproofing" were reported to be areas of work in which the financial impact of error is significant. Therefore these categories were combined and included in the analysis using the Delphi Method.

The first question of the Delphi Method analysis required each expert to rank the areas of work according to the financial impact of error in each area. The results of the analysis using the Delphi Method are summarised below. The changes in the results between the first and second round of the Delphi Method analysis were small.

	Rank	**Civil Engineering**	**Building**	**Across the industry**
More Significant	1	Concrete Works	Mechanical Systems (including BMS)	Concrete Works
	2	Mechanical Systems (including BMS) Setting Out	Concrete Works Facades / Cladding	Mechanical Systems (including BMS)
	3			Electrical Systems
	4	Electrical Systems Finishes	Electrical Systems	Facades / Cladding
	5		Damage to completed works Roofing	Finishes
	6	Basement Waterproofing Drainage		Basement Waterproofing
	7		Basement Waterproofing	Setting Out
	8	Facades / Cladding Piling Steelwork coatings	Finishes	Damage to completed works
	9		Drainage	Drainage
	10		Setting Out	Roofing
	11	Damage to completed works	Piling	Piling
	12	Roofing	Steelwork coatings	Steelwork coatings
Less Significant	13	Roads and Pavements	Roads and Pavements	Roads and Pavements

The averages of the scores assigned are summarised in the chart below.



5.2.2. Ranking of the root causes of error according to financial impact

The analysis using the Grounded Theory Method provided us with a list of the root causes of error that were reported within our study group. The ranking is by frequency of reporting and does not necessarily reflect the economic significance as some of the root causes whilst frequent may have low cost impact. There was some overlap between the categories which resulted from the Grounded Theory Method, and the review of the results indicated that some of the categories would be better separated into a number of sub-categories.

For the Delphi Method analysis we required a concise list of the root causes of error. The table below summaries the adjusted categories and the amended category titles which were adopted for the Delphi Method analysis.

Results of the analysis using the Grounded Theory Method		**Categories taken forward for analysis using the Delphi Method to identify the areas of work in which error has the most significant financial impact.**	
Root causes of error that were reported within our study group. The ranking here is by frequency of reporting.	Comments	Consolidated categories for analysis using the Delphi Method	Category titles as used in the analysis using the Delphi Method
1. Management and Planning		1. Management and Planning	Inadequate planning (from task through to project level)
			Inadequate professional skills (contract & sub-contract management)
			Poor site conditions and access
			Contractual arrangements
2. Communications		2. Communications	Ineffective communication between team members
			Ineffective relationships between team members
			Poorly communicated design information
3. Workmanship	Note that from the discussions it was understood that this relates largely to planning skills by the trades rather than to technical competence	3. Workmanship 10. Inadequate training	Inadequate trade skills

Results of the analysis using the Grounded Theory Method		**Categories taken forward for analysis using the Delphi Method to identify the areas of work in which error has the most significant financial impact.**	
Root causes of error that were reported within our study group. The ranking here is by frequency of reporting.	Comments	Consolidated categories for analysis using the Delphi Method	Category titles as used in the analysis using the Delphi Method
4. Design		4. Design	Poorly coordinated and incorrect design information
5. Materials		5. Materials	Deficient materials or components
6. Interface Design and Management		6. Interface Design and Management	Poor interface management and design
7. Commercial Pressures		7. Commercial Pressures 15. Design fees 16. Late surveys and investigations 17. Programme 18. Time	Excessive commercial (financial and time) pressures
8. Late changes		8. Late changes	Late design changes
9. Information overload		9. Information overload	Information overload
10. Inadequate training	Combined with workmanship		
11. Setting out	Not a cause		
12. Fabrication	Not a cause		
13. Lack of focus on quality		13. Lack of focus on quality	Inadequate supervisory skills
14. Designers having a poor understanding of details		14. Designers having a poor understanding of details	Inadequate attention paid in the design to construction
15. Design fees	Combined with commercial pressures		
16. Late surveys and investigations	Combined with commercial pressures		
17. Programme	Combined with commercial pressures		

Results of the analysis using the Grounded Theory Method		Categories taken forward for analysis using the Delphi Method to identify the areas of work in which error has the most significant financial impact.	
Root causes of error that were reported within our study group. The ranking here is by frequency of reporting.	Comments	Consolidated categories for analysis using the Delphi Method	Category titles as used in the analysis using the Delphi Method
18. Time	Combined with commercial pressures		
19. Core skills	Combined with management and workmanship for the Delphi Method Analysis		
20. Outside of core geographical range of work	See note A.		
21. Motivation	This category overlapped with comments that had been assigned to the management and workmanship categories. It was therefore retained, but retitled for the Delphi Method analysis.	21. Motivation	Poor culture in relation to quality

Notes

A. Following the structured interviews it was understood that this root cause was not the one in which the financial impact of error was most significant. To allow the experts to focus on the key issues this category was therefore omitted from the analysis using the Delphi Method.

The second question of the Delphi Method analysis required each expert to assign an importance of each of the root causes on a scale of 1 to 10. The results of the analysis using the Delphi Method are summarised below. The changes in the results between the first and second round of the Delphi Method analysis were small.

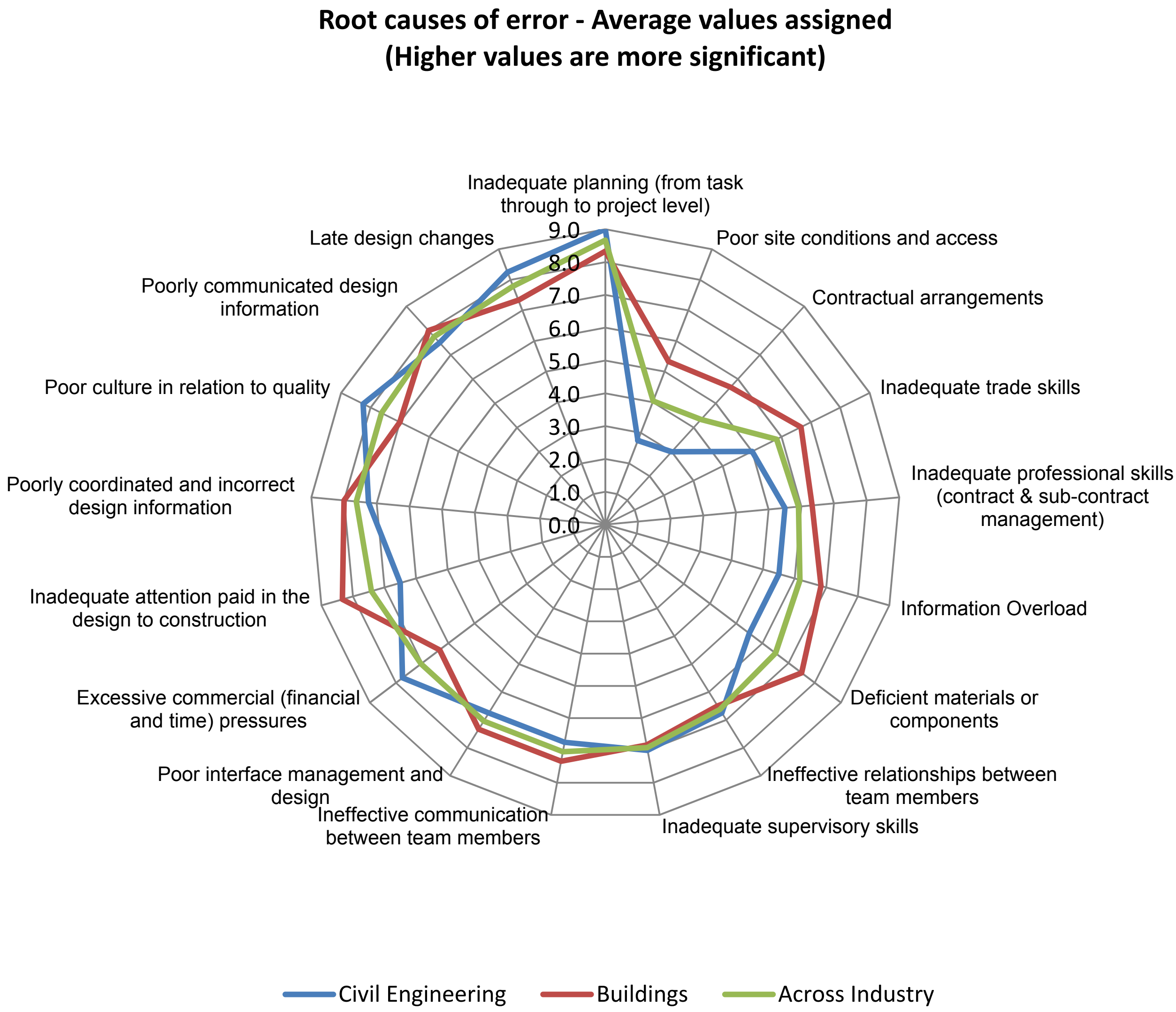
More Significant

Rank	Civil Engineering	Buildings	Across the industry
1.0	Inadequate planning (from task through to project level)	Inadequate planning (from task through to project level) Inadequate attention paid in the design to construction	Inadequate planning (from task through to project level)
2.0	Late design changes Poor culture in relation to quality		Late design changes
3.0		Poorly communicated design information Poorly coordinated and incorrect design information	Poorly communicated design information
4.0	Excessive commercial (financial and time) pressures		Poor culture in relation to quality Poorly coordinated and incorrect design information
5.0	Poorly communicated design information	Deficient materials or components	
6.0	Poorly coordinated and incorrect design information	Late design changes Poor interface management and design Ineffective communication between team members	Inadequate attention paid in the design to construction
7.0	Inadequate supervisory skills		Excessive commercial (financial and time) pressures Poor interface management and design Ineffective communication between team members

Rank	Civil Engineering	Buildings	Across the industry
8.0	Poor interface management and design Ineffective communication between team members Ineffective relationships between team members		
9.0		Poor culture in relation to quality	
10.0		Inadequate supervisory skills Information overload	Inadequate supervisory skills
11.0	Inadequate attention paid in the design to construction		Ineffective relationships between team members
12.0	Deficient materials or components Information overload Inadequate professional skills (contract & sub-contract management)	Inadequate trade skills	Deficient materials or components
13.0		Ineffective relationships between team members	Information overload
14.0		Excessive commercial (financial and time) pressures Inadequate professional skills (contract & sub-contract management)	Inadequate professional skills (contract & sub-contract management)
15.0	Inadequate trade skills		Inadequate trade skills
16.0	Contractual arrangements	Contractual arrangements	Contractual arrangements
17.0	Poor site conditions and access	Poor site conditions and access	Poor site conditions and access

Less Significant

The averages of the scores assigned to each of the root causes are summarised in the chart below.

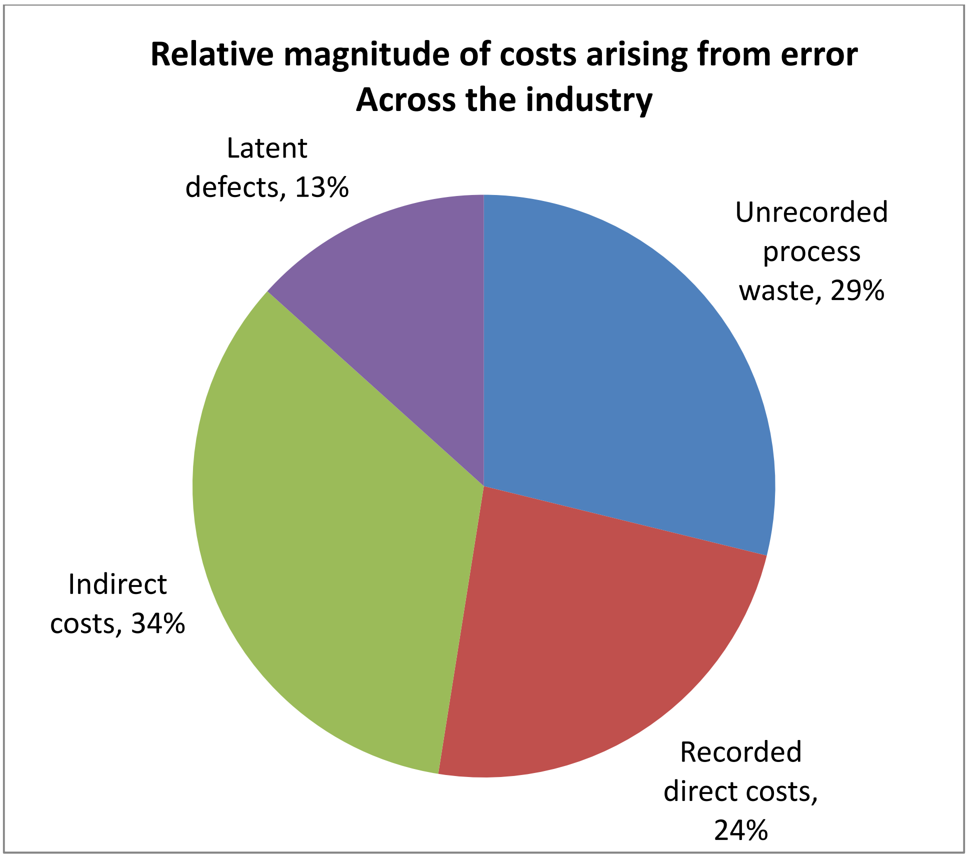


5.2.3. The relative financial cost of error

In the third question of the Delphi Method analysis the experts were asked to assess the relative financial impact of: the direct costs of error, the indirect costs of error, latent defects and unrecorded process waste. The estimated distribution of the costs was similar for the Civil Engineering and Building sectors. The results are summarised in the table and chart below.

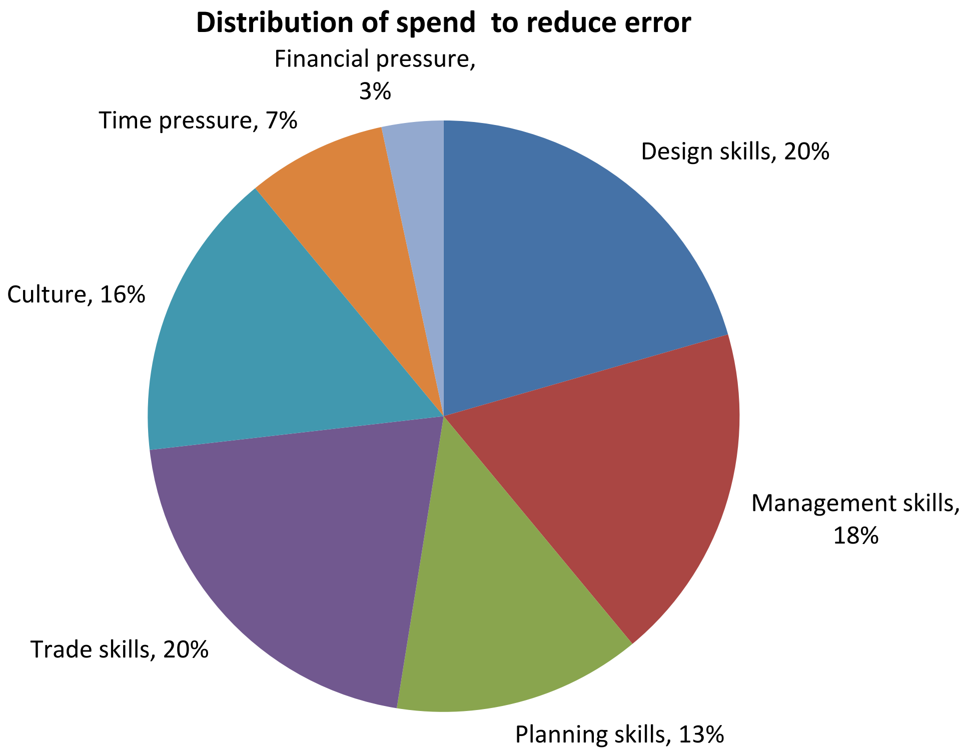
Relative magnitude of costs arising from error

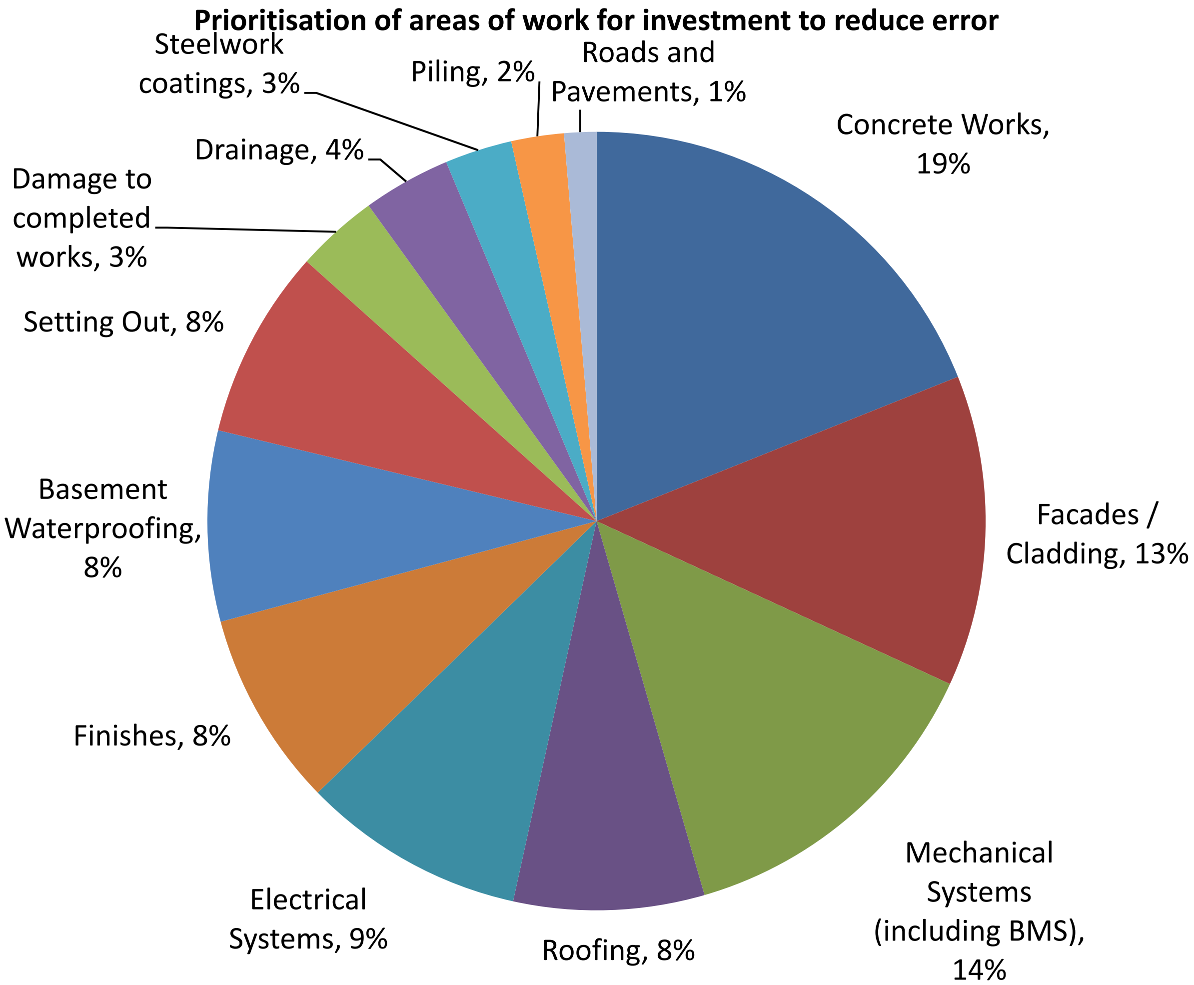
	Civil Engineering	Building	Across industry
Unrecorded process waste	28%	31%	29%
Recorded direct costs	25%	22%	24%
Indirect costs	33%	37%	34%
Latent defects	15%	11%	13%



5.2.4. Assessment of methods of reducing the financial impact of error in the construction industry.

In the fourth question the experts were asked first to assess how spend should be distributed across the areas of work to achieve the maximum reduction in the cost of error, and second to assess how spend should be allocated within each of the areas of work. The results are summarised in the charts below.

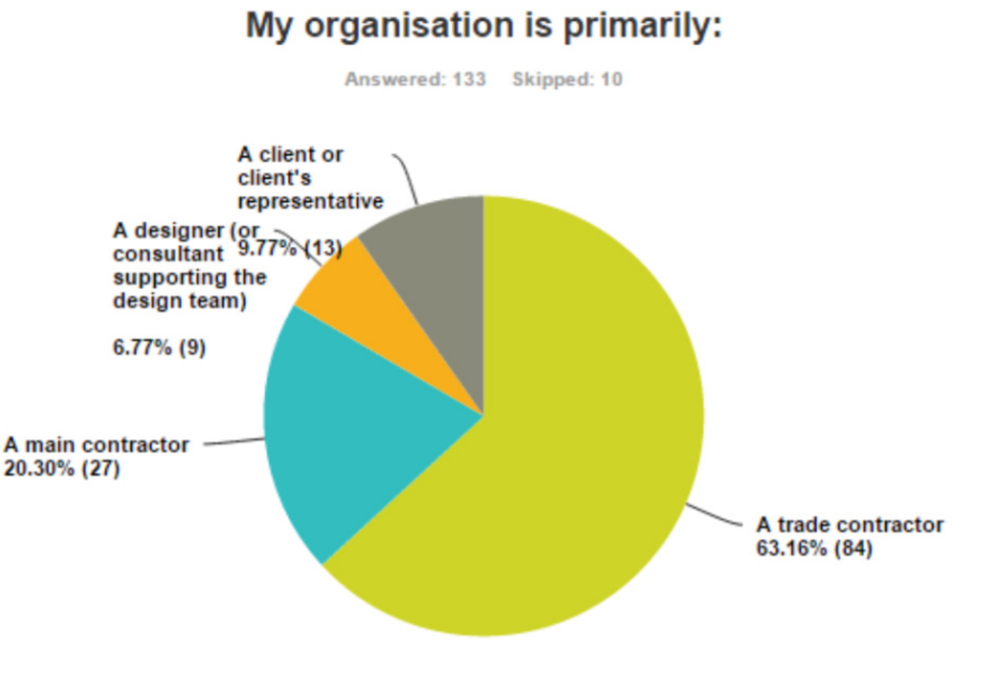



Prioritisation of areas of work for investment to reduce error
Steelwork coatings, 3%
Piling, 2%
Roads and Pavements, 1%
Concrete Works, 19%
Drainage, 4%
Damage to completed works, 3%
Setting Out, 8%
Basement Waterproofing, 8%
Facades / Cladding, 13%
Finishes, 8%
Mechanical Systems (including BMS), 14%
Electrical Systems, 9%
Roofing, 8%

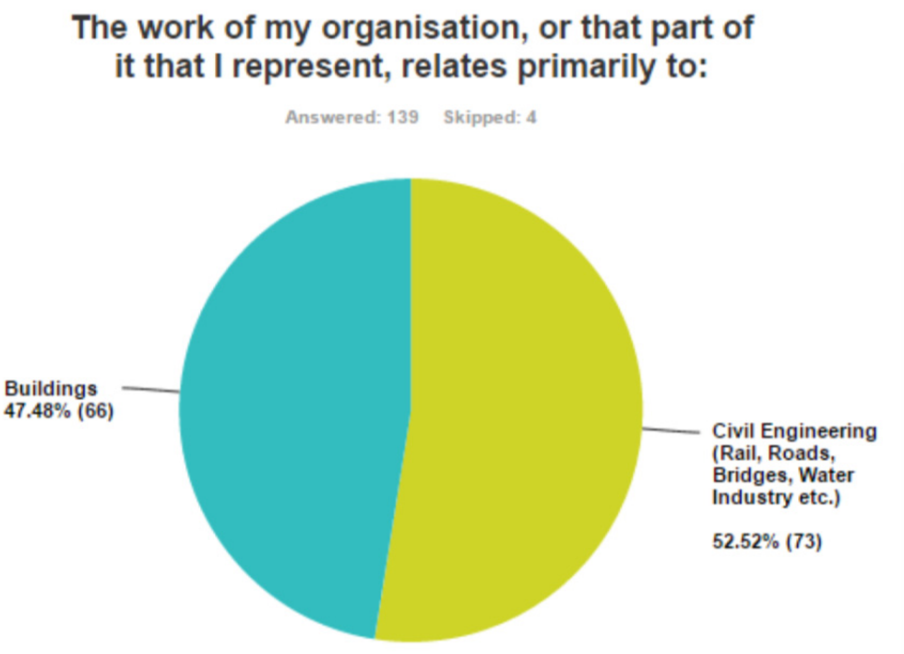
5.3. Online survey results

There were 143 responses to the online survey. However not everyone that started the survey answered all parts of each of the two detailed questions, the number of responses to each part varied from 59 to 73 of the total 143 participants.

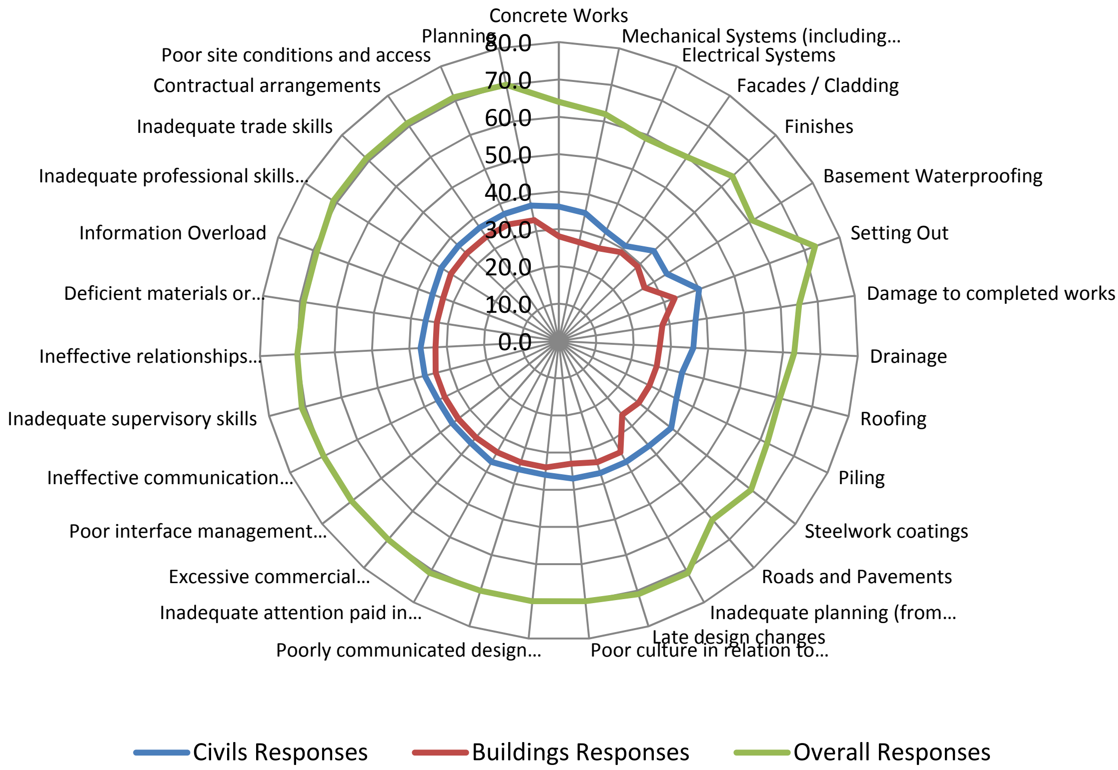
The majority of respondents were trade contractors.



The work of the organisations, or that part of it that the respondents represented, was approximately evenly distributed between Civil Engineering and Buildings.



Number of respondents to the online survey questions

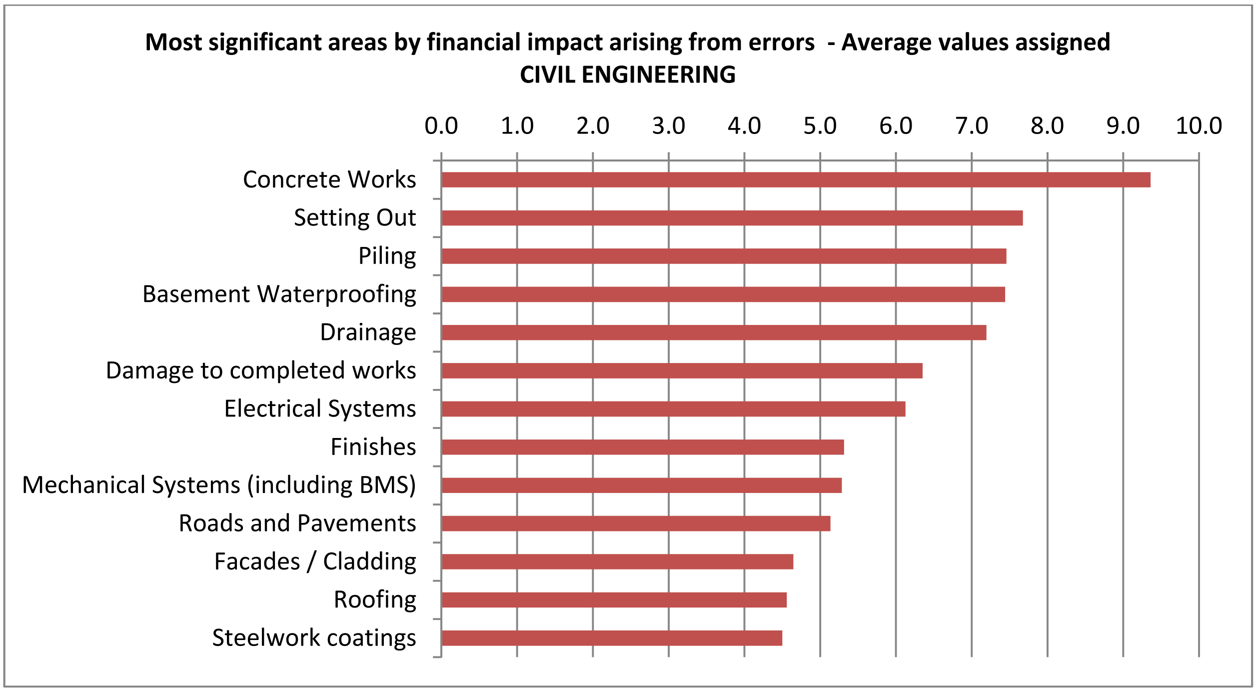


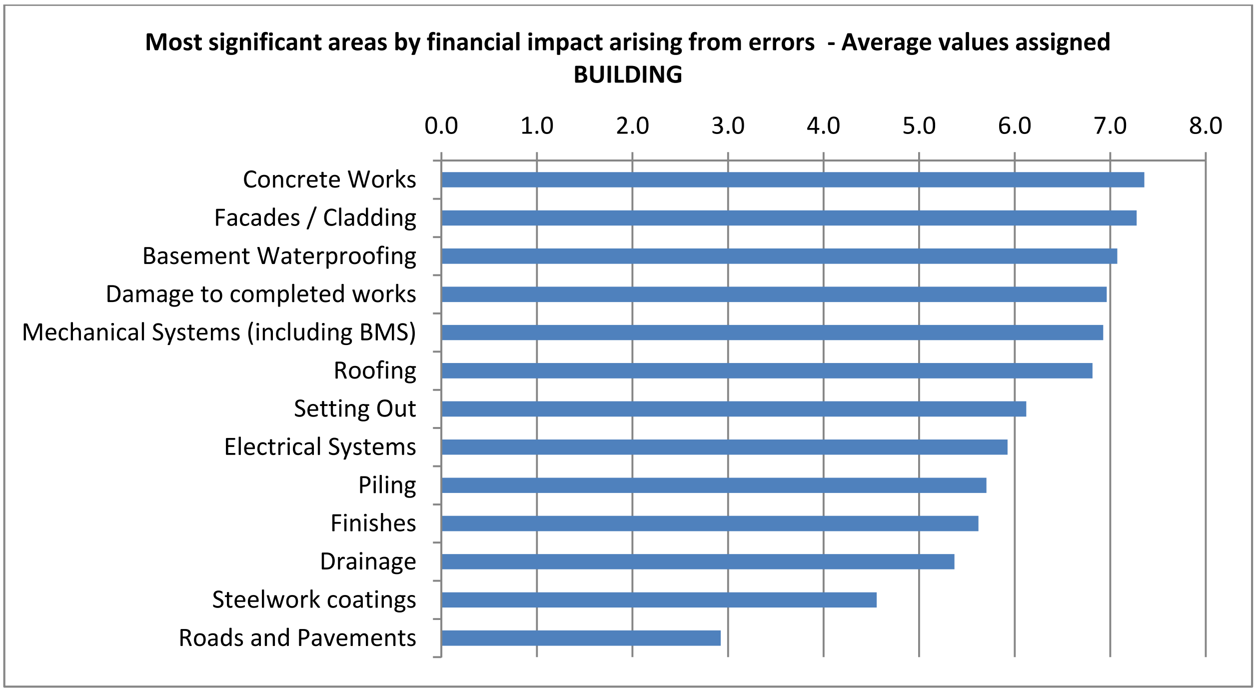
5.3.1. Ranking of the areas of work according to the financial impact of error

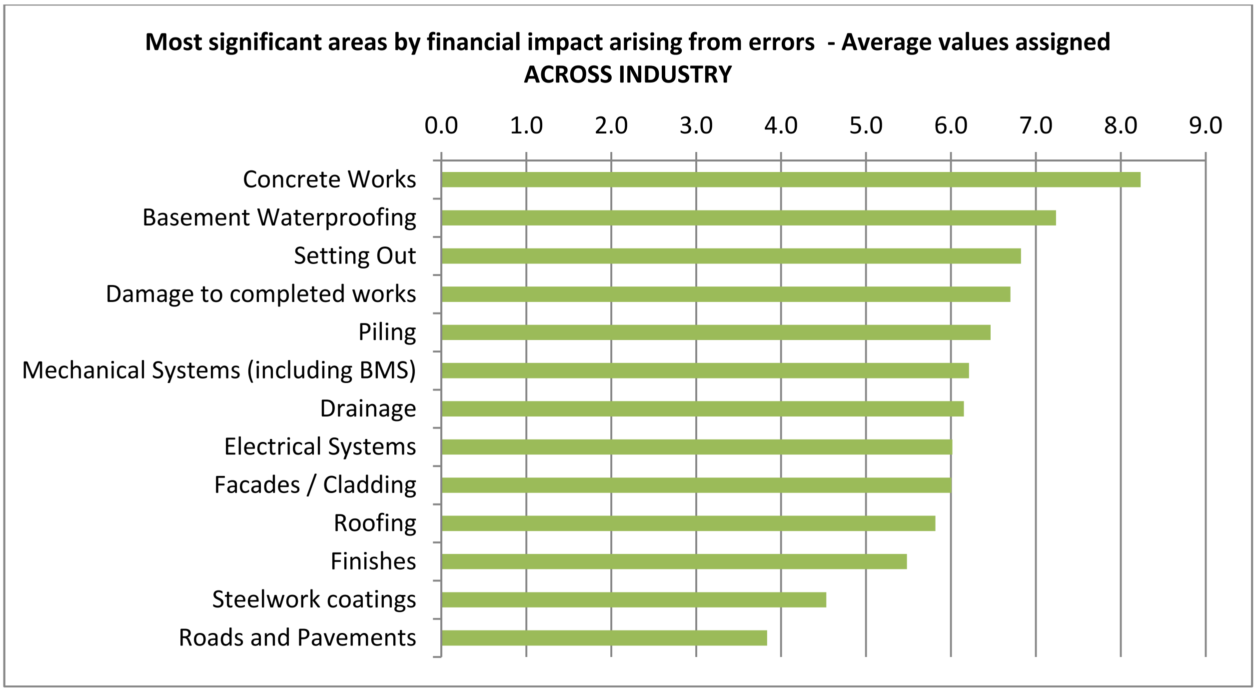
The online survey respondents were asked the same question that the experts were asked during the Delphi Method Analysis. The respondents were asked to rank the areas of work according to the financial impact of error in each area. The results of the online survey are summarised below.

	Rank	Civil Engineering	Buildings	Across the industry
More Significant	1	Concrete Works	Concrete Works	Concrete Works
	2	Setting Out	Mechanical Systems (including BMS)	Mechanical Systems (including BMS)
	3	Piling	Electrical Systems	Electrical Systems
	4	Basement Waterproofing	Facades / Cladding	Facades / Cladding
	5	Drainage	Finishes	Finishes
	6	Damage to completed works	Basement Waterproofing	Basement Waterproofing
	7	Electrical Systems	Setting Out	Setting Out
	8	Finishes	Damage to completed works	Damage to completed works
	9	Mechanical Systems (including BMS)	Drainage	Drainage
	10	Roads and Pavements	Roofing	Roofing
	11	Facades / Cladding	Piling	Piling
	12	Roofing	Steelwork coatings	Steelwork coatings
Less Significant	13	Steelwork coatings	Roads and Pavements	Roads and Pavements

The averages of the scores assigned are summarised in the charts below.







Further survey results are available in Appendix A.

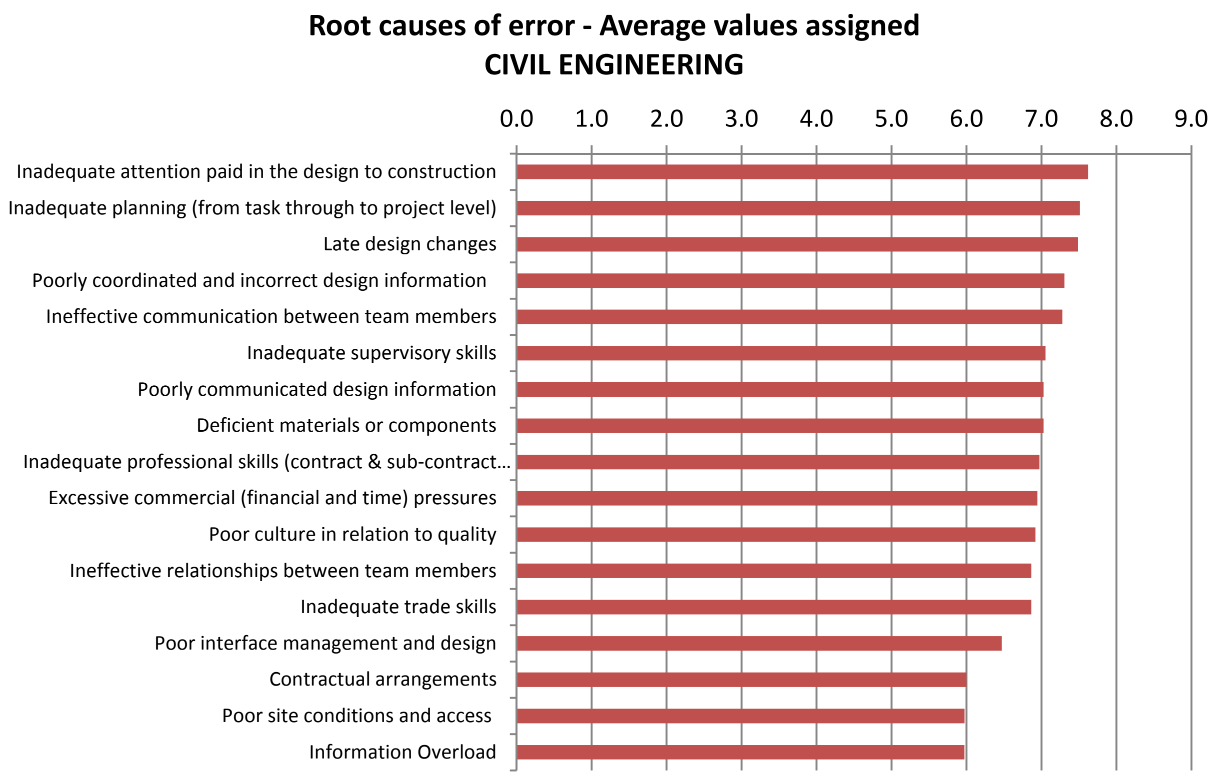
5.3.2. Ranking of the root causes of error according to financial impact

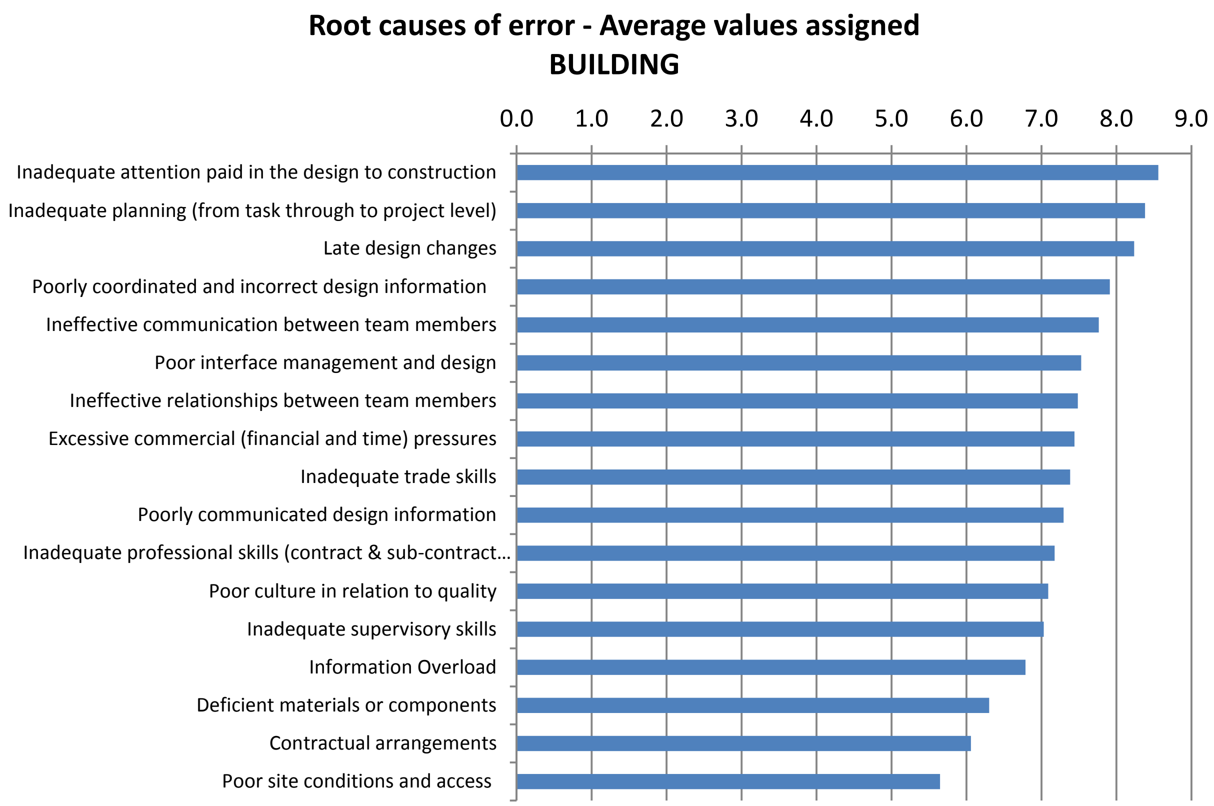
The online survey respondents were asked the same question that the experts were asked during the Delphi Method Analysis. The respondents were asked to assign an importance of each of the root causes on a scale of 1 to 10. The results of the on line survey are summarised below.

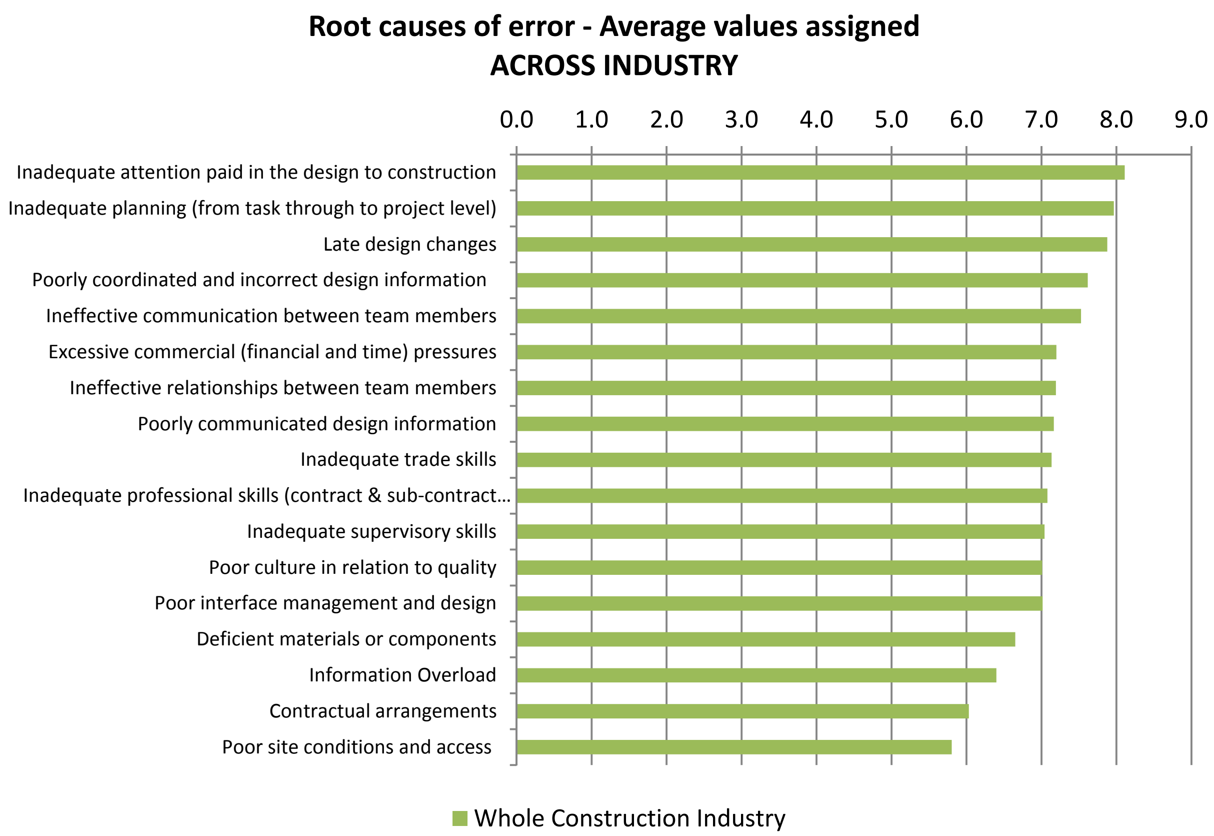
	Rank	Civil Engineering	Buildings	Across the industry
More Significant	1	Inadequate attention paid in the design to construction	Inadequate attention paid in the design to construction	Inadequate attention paid in the design to construction
	2	Inadequate planning (from task through to project level)	Inadequate planning (from task through to project level)	Inadequate planning (from task through to project level)
	3	Late design changes	Late design changes	Late design changes
	4	Poorly coordinated and incorrect design information	Poorly coordinated and incorrect design information	Poorly coordinated and incorrect design information
	5	Ineffective communication between team members	Ineffective communication between team members	Ineffective communication between team members
	6	Inadequate supervisory skills	Poor interface management and design	Excessive commercial (financial and time) pressures
	7	Poorly communicated design information	Ineffective relationships between team members	Ineffective relationships between team members
	8	Deficient materials or components	Excessive commercial (financial and time) pressures	Poorly communicated design information
	9	Inadequate professional skills (contract & sub-contract management)	Inadequate trade skills	Inadequate trade skills
	10	Excessive commercial (financial and time) pressures	Poorly communicated design information	Inadequate professional skills (contract & sub-contract management)
Less Significant	11	Poor culture in relation to quality	Inadequate professional skills (contract & sub-contract management)	Inadequate supervisory skills

Rank	Civil Engineering	Buildings	Across the industry
12	Ineffective relationships between team members	Poor culture in relation to quality	Poor culture in relation to quality
13	Inadequate trade skills	Inadequate supervisory skills	Poor interface management and design
14	Poor interface management and design	Information Overload	Deficient materials or components
15	Contractual arrangements	Deficient materials or components	Information Overload
16	Poor site conditions and access	Contractual arrangements	Contractual arrangements
17	Information Overload	Poor site conditions and access	Poor site conditions and access

The averages of the scores assigned are summarised in the charts below.







Further survey results are available in Appendix A.

5.3.3. Comments

The table below includes all of the comments that were received.

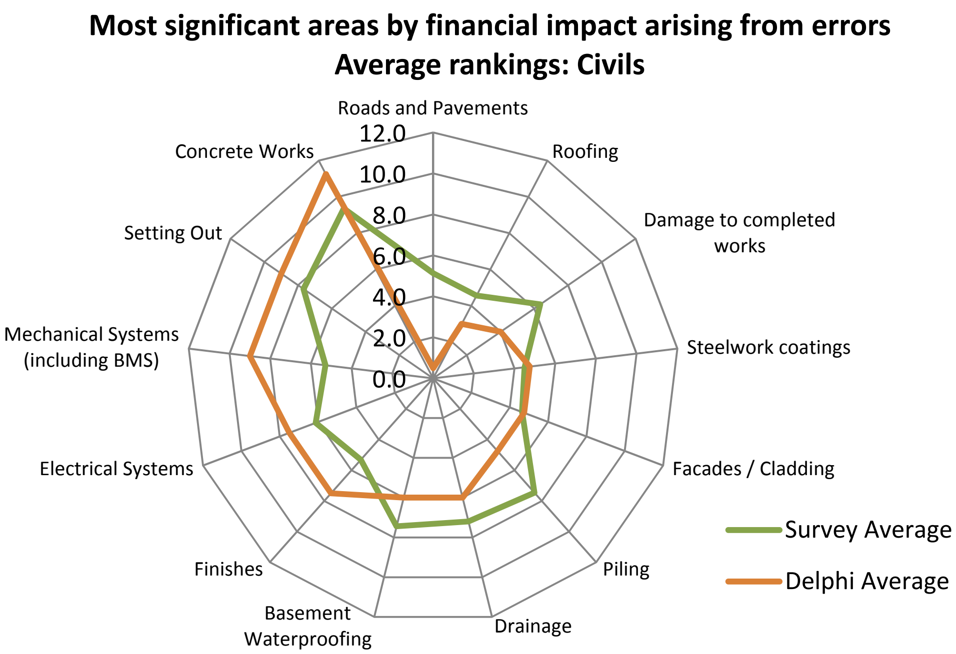
The work of my organisation, or that part of it that I represent, relates primarily to:	My organisation is primarily:	Are there any comments that you would like to add?
Buildings	A main contractor	good work tackling the 'big issue' of defects and the massive associated costs!
Buildings	A trade contractor	The quality and timing of design information we receive from the professional teams is at an all time low. Whether trades are not appointed earlier enough to help them finish off their designs or whether they are not given enough time to complete their jobs to a reasonable level or whether they simply don't have the skills anymore i'm not too sure.
Buildings	A trade contractor	Main contractors have, in the main, lost the skills required to successfully manage the supply chain - fro placing the order - through design and delivery. Tier 1 management contractors may well have seen their day.
Buildings	A trade contractor	Poor initial design and incorrect specification lead to costly errors
Buildings	A trade contractor	The construction industry has a huge skills problem from top to bottom. The lack of training. Persons who have no pride in the work or just simply don't care. My personal opinion is that is isn't just a construction problem but society, in all workplaces the lack of training and people who no longer care. But on a brighter note we are trying to do our little bit and have a healthy apprenticeship programme and are trying in our own small way to train and change the construction industry for the better.
Buildings	A trade contractor	The culture of build it for the least price in the least time without really knowing what the final design will be when the project starts
Buildings	A trade contractor	Apologies but the questions are open to far too much interpretation so I have not answered Q 3
Buildings	A trade contractor	trade packages are not procured early enough
Buildings	A trade contractor	Have better interface meeting at an early stage with all key contractors, civil, electrical, mechanical etc , this can have a positive impact and saves problems later down the line.
Civil Engineering	A main contractor	Q3 category 11-13 not applicable
Civil Engineering	A trade contractor	Not enough time spent planning and checking on most sites prior to commencement.
Civil Engineering	A trade contractor	Difficult to evaluate some areas
Civil Engineering	A trade contractor	Last minute involvement on trade packages. Design information inadequate. Late design changes The above are major contributors to mistakes
Civil Engineering	A trade contractor	Good planning and clear concise and relevant information flow is essential to be able to get things right.
Civil Engineering	A trade contractor	Engaging trades earlier in the process would help to identify design deficiencies.

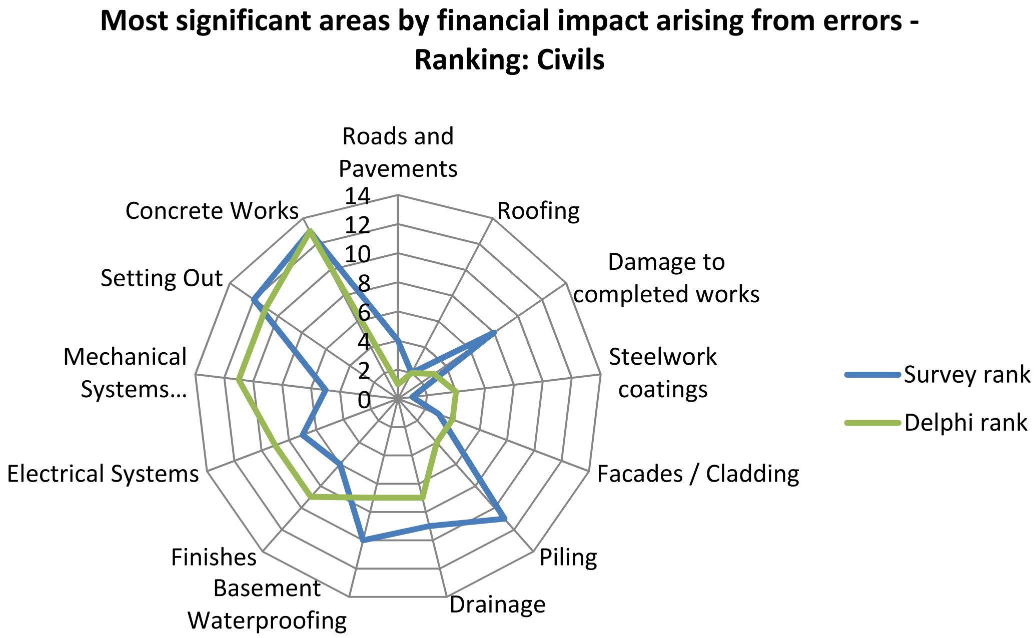
5.4. Comparison of the Delphi Method analysis results with the online survey results

5.4.1. Ranking of the areas of work according to the financial impact of error

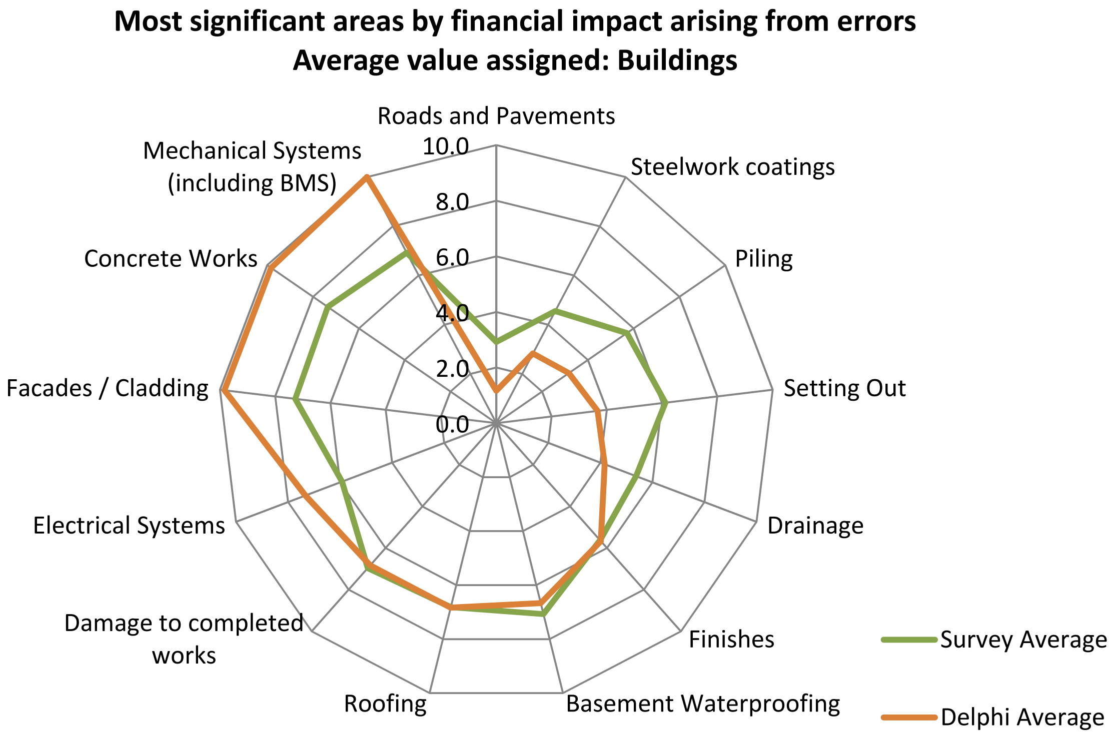
The charts below compare the rankings assigned in the Delphi Method analysis with the rankings assigned in the online survey.

Civil Engineering

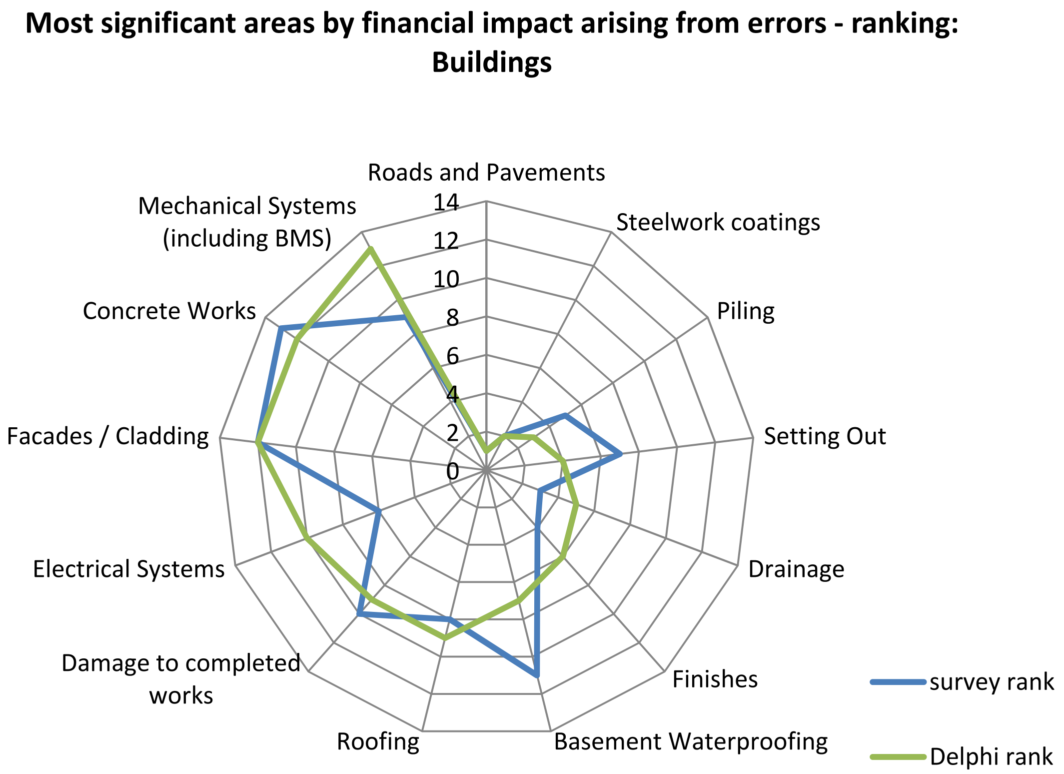




Buiding

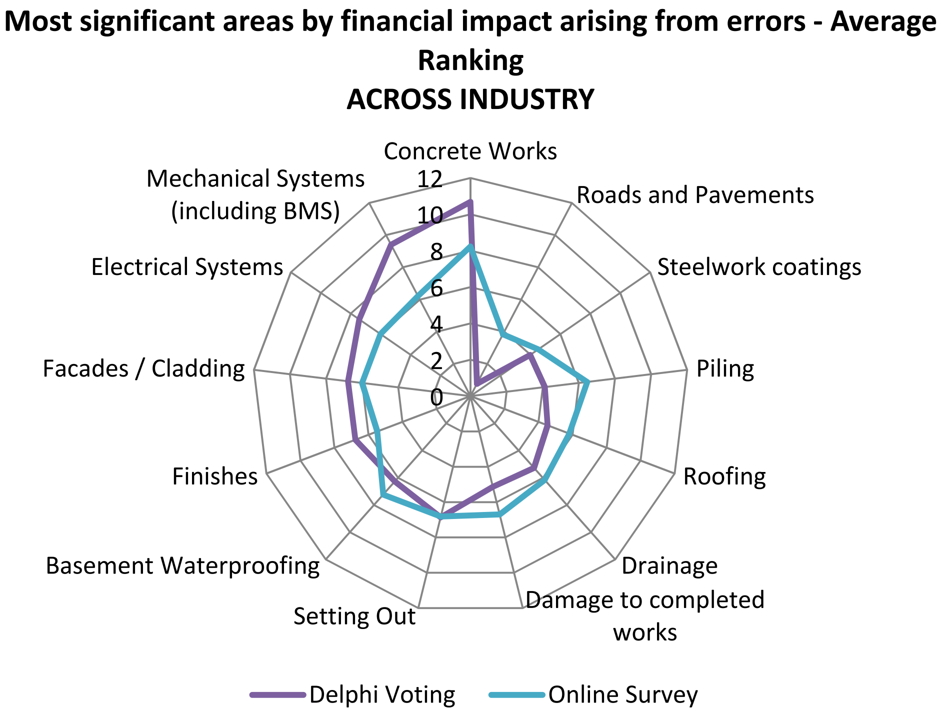


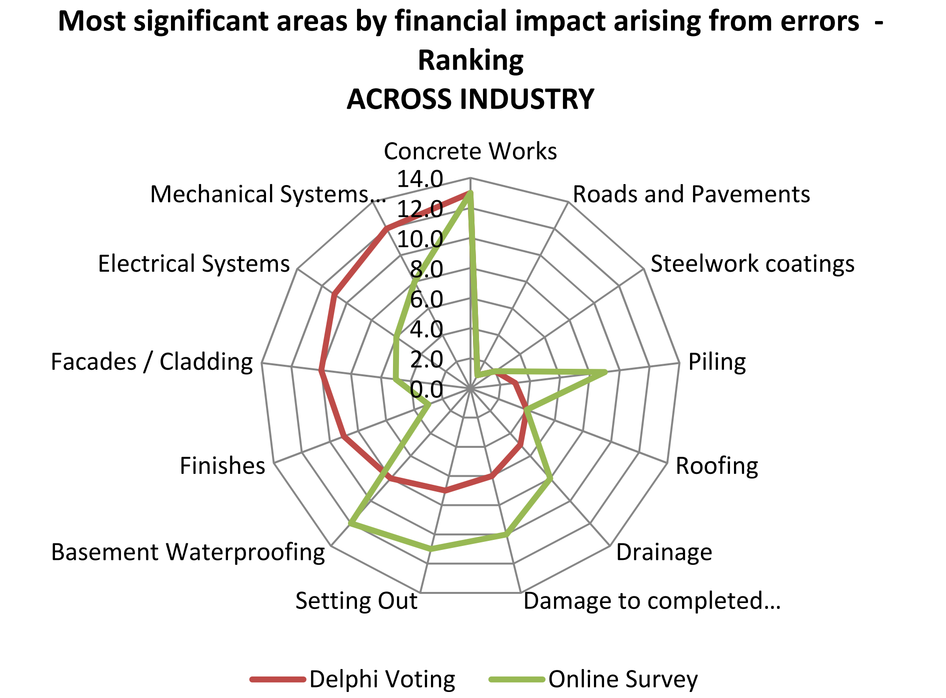
Most significant areas by financial impact arising from errors
Average value assigned: Buildings
Roads and Pavements
Steelwork coatings
Piling
Setting Out
Drainage
Finishes
Basement Waterproofing
Roofing
Damage to completed works
Electrical Systems
Facades / Cladding
Concrete Works
Mechanical Systems (including BMS)
10.0
8.0
6.0
4.0
2.0
0.0
Survey Average
Delphi Average



Most significant areas by financial impact arising from errors - ranking: Buildings
Roads and Pavements
Steelwork coatings
Piling
Setting Out
Drainage
Finishes
Basement Waterproofing
Roofing
Damage to completed works
Electrical Systems
Facades / Cladding
Concrete Works
Mechanical Systems (including BMS)
14
12
10
8
6
4
2
0
survey rank
Delphi rank

Across industry



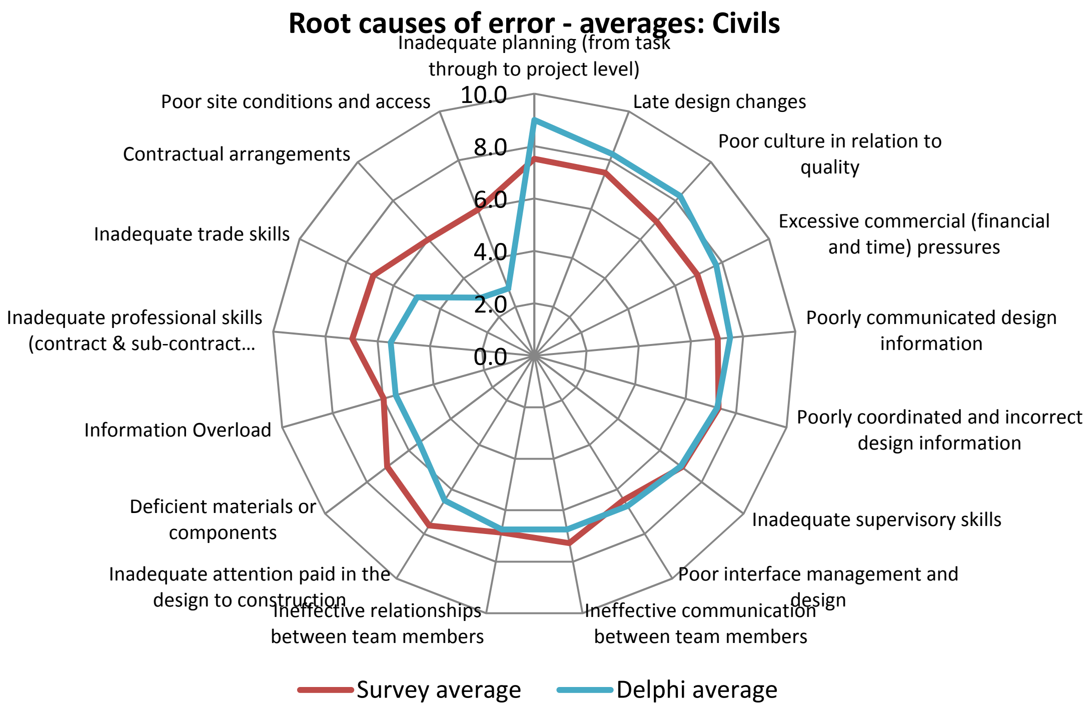


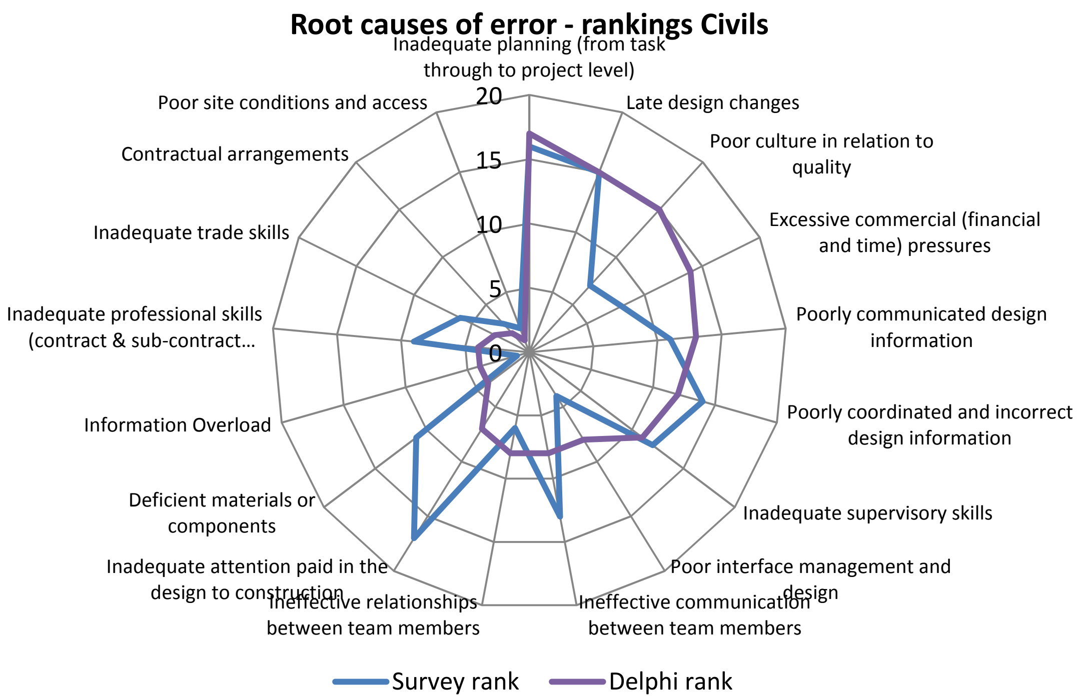
Note that the apparently large discrepancies between the rankings are the result of small differences in the averages: the apparently large discrepancies are a reflection of the fact that once the results of the Civil Engineering and Building sectors are combined there is little difference in the average rankings for the work areas between “Damage to completed elements” and “Electrical Systems”.

5.4.2. Ranking of the root causes of error according to financial impact

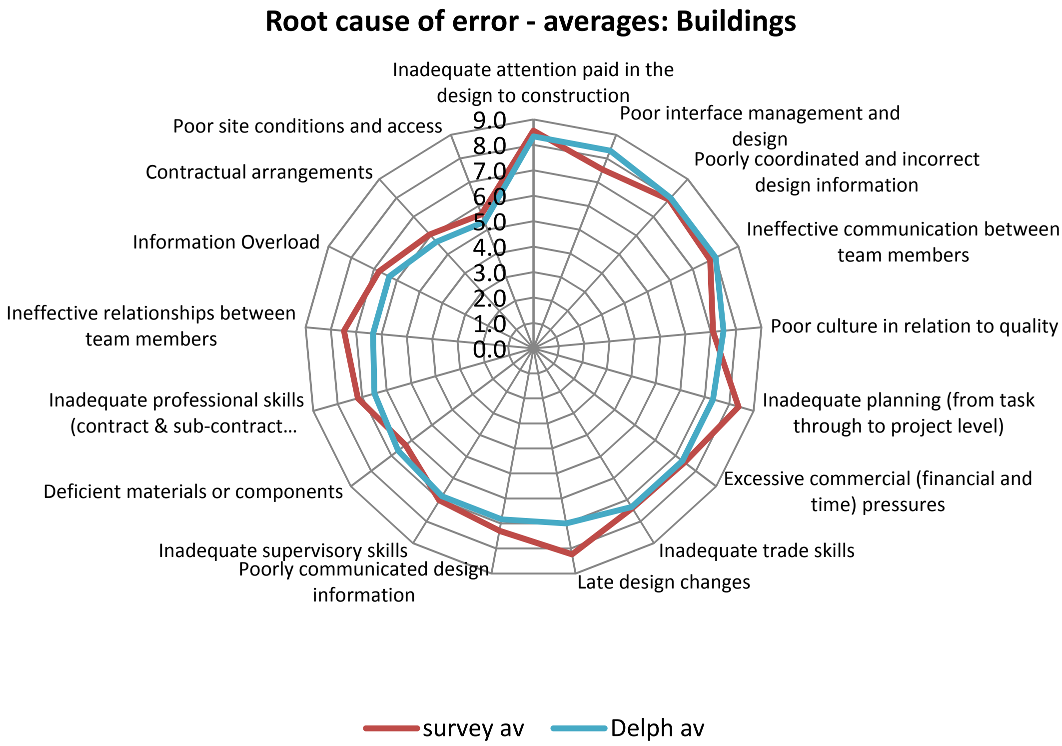
The charts below compare the rankings assigned in the Delphi Method analysis with the rankings assigned in the online survey.

Civil Engineering

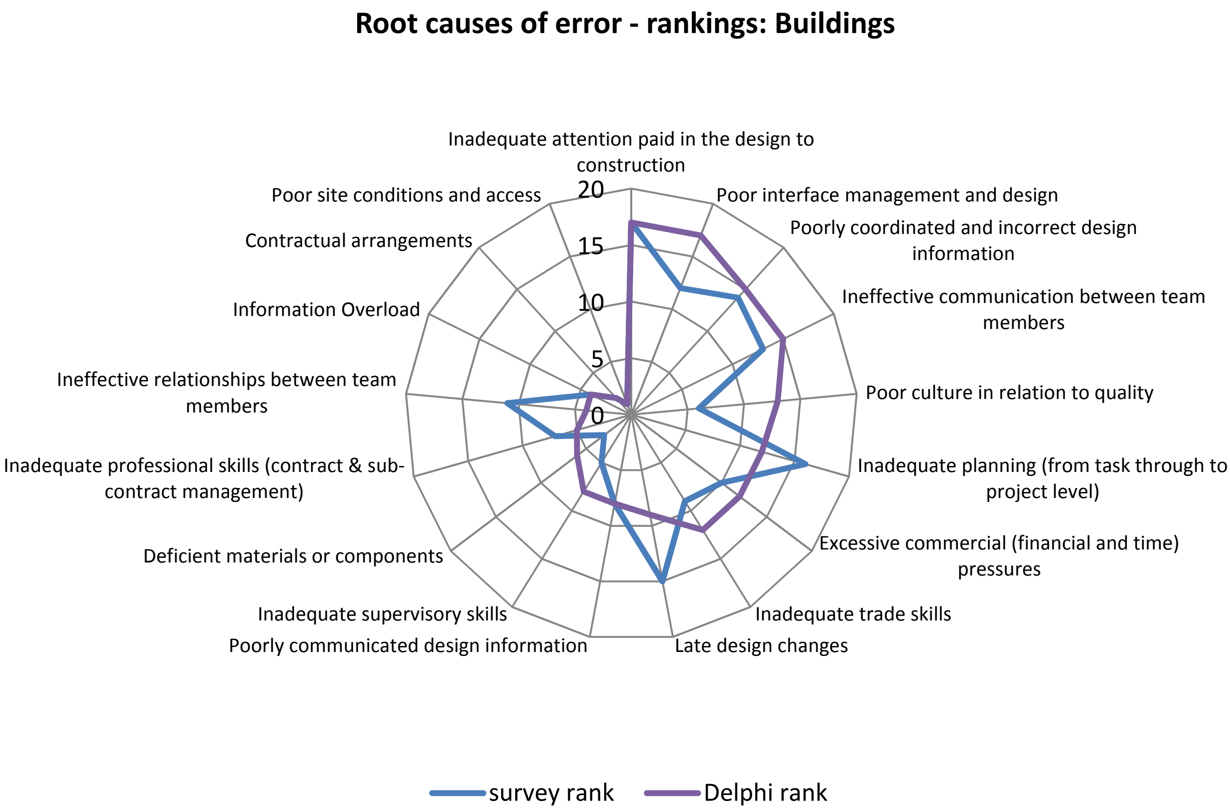




Building

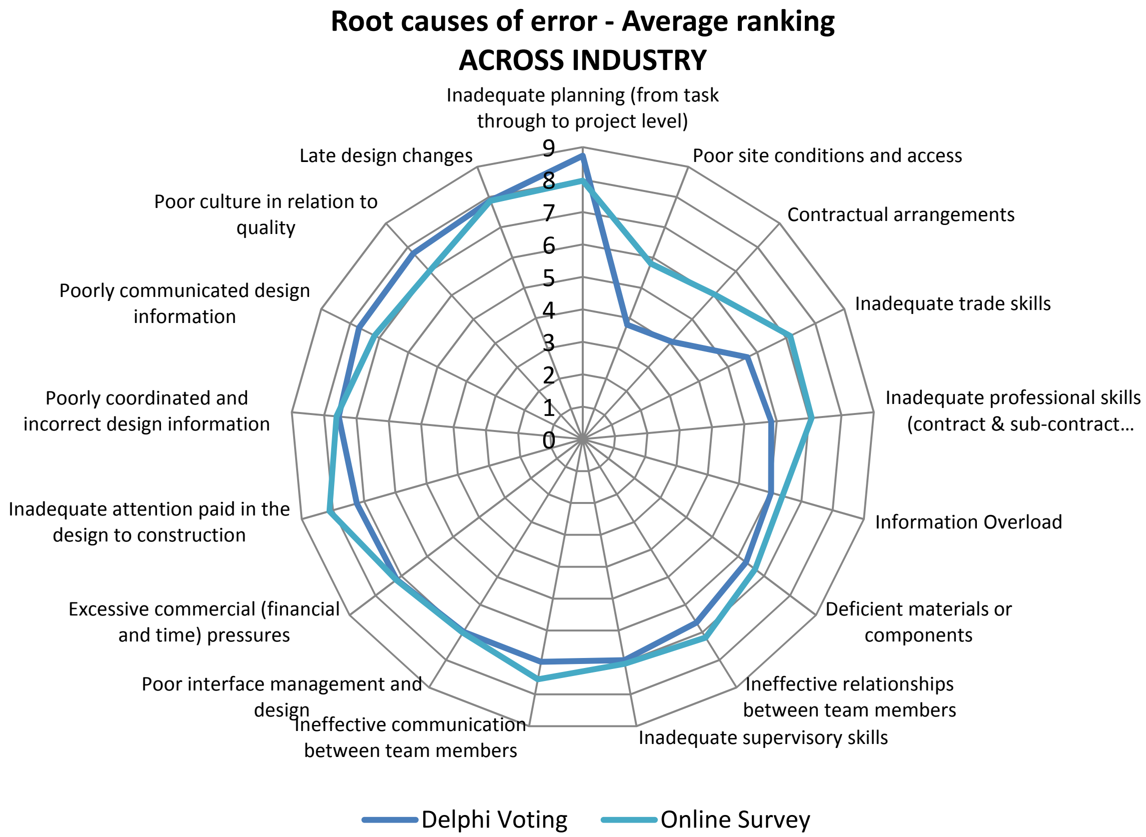


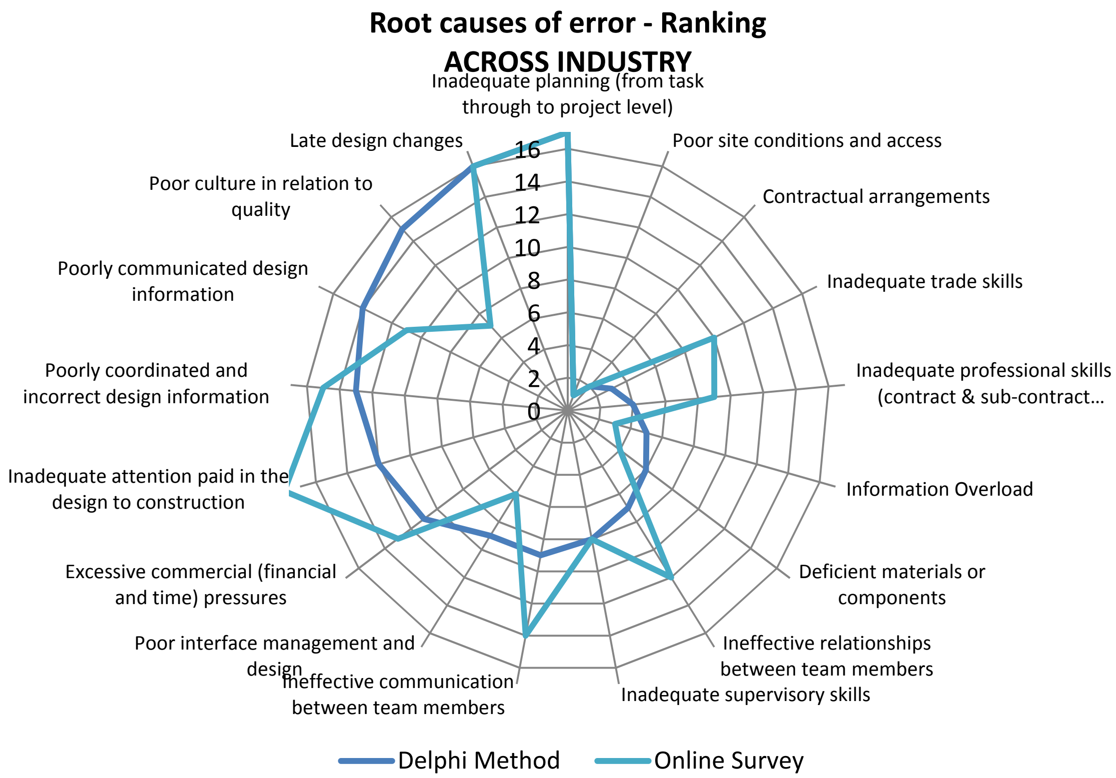
Root cause of error - averages: Buildings
Inadequate attention paid in the design to construction
Poor interface management and design
Poorly coordinated and incorrect design information
Ineffective communication between team members
Poor culture in relation to quality
Inadequate planning (from task through to project level)
Excessive commercial (financial and time) pressures
Inadequate trade skills
Late design changes
Poorly communicated design information
Inadequate supervisory skills
Deficient materials or components
Inadequate professional skills (contract & sub-contract...
Ineffective relationships between team members
Information Overload
Contractual arrangements
Poor site conditions and access
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
survey av
Delph av



Root causes of error - rankings: Buildings
Inadequate attention paid in the design to construction
Poor interface management and design
Poorly coordinated and incorrect design information
Ineffective communication between team members
Poor culture in relation to quality
Inadequate planning (from task through to project level)
Excessive commercial (financial and time) pressures
Inadequate trade skills
Late design changes
Poorly communicated design information
Inadequate supervisory skills
Deficient materials or components
Inadequate professional skills (contract & sub-contract management)
Ineffective relationships between team members
Information Overload
Contractual arrangements
Poor site conditions and access
20
15
10
5
0
survey rank
Delphi rank

Across industry





5.5. Literature Review

The literature review is presented in Appendix B. The key findings are summarised below.

5.5.1. Errors

While many organisations maintain rework tracking systems, there is significant variation in the systems used.

There are many ways of describing construction error and the consequences of error. One system used by Reason (1995) usefully categorised errors as:

- Failures of intention where the design or implementation plan is inadequate.
- Failures of execution where actions do not go as planned.
- Deliberate violations where the works deliberately deviate from the plan.

The desk research demonstrates that when we look for the causes of an error, it is useful to understand not only the physical root cause but also the systemic and behavioural context, why the problem by-passed opportunities for that problem to be captured, before becoming manifest as an error requiring rework.

5.5.2. Costs

Several recent studies have provided support for the use of 5% as an average approximation of the cost of rework in construction. For example, a study in 2009 of 177 construction projects found that the average owner reported rework cost was 5% across all projects. Further, research by the USA's Construction Industry Institute (CII) reveals that direct costs caused by rework average 5% of total construction costs (CII 2005) (but range from 0-25%). This correlates well with the information that we have received from the steering group.

However, these figures relate only to the cost of errors and defects which are recorded. From our research it is apparent that there is a significant further cost of rework which is completed before cost information is captured. The figures relate to the direct cost of errors. From our research it is apparent that there is a significant further indirect cost of errors defects.

The implication of this is that the UK construction industry spends substantially more than £5bn per annum in rectifying errors and defects.

5.5.3. Root Causes

The literature identifies the following principal root causes of error:

- Client changes.
- Design errors by both the client's design team and the contractor's design team.
- Failures in planning the execution of site works.
- Time pressures.
- Cost pressures.

- The fragmentation of the industry.

5.5.4. Conclusions

Reducing client changes, improving design, and improving project planning are typically identified as the means by which the cost of reworking can be most effectively reduced.

The Construction Industry Institute (CII) has presented what appears to be a useful Field Rework Index, a simple 14 question survey that is reported to provide a reasonable indication of the risk of rework on a project.

6. Observations and Conclusions

6.1. Scarcity of quantitative data

There is significant variation in whether and how companies record the cost of error. Few of the organisations that we interviewed had detailed quantitative data relating to errors. Where information was available the financial details generally related solely to the direct cost of error to the organisation being interviewed, rarely was information available on the cost (direct or indirect) to other parties. All of the systems that we saw only capture the direct cost of error, and do that only partially.

The desk study indicates that this is common across the construction industry. Generally research has been completed on particular projects or sectors to inform the works referenced in the desk study.

6.2. Review of the analysis using the Grounded Theory Method

The research team had good access to a broad spectrum of highly experienced individuals who worked for leading companies in the UK construction industry. Despite this the sample size necessarily represented a very small part of the UK construction industry. However, there were strong common themes that arose from the interviews and these themes are compatible with the results of the studies referenced in the literature review. We believe that it is reasonable to consider that the structured interviews successfully identified the most significant root causes of error in the UK construction industry, as well as the areas of work in which error occurs with the greatest frequency.

The majority of the people interviewed worked for Tier 1 Contractors. This selection was intentional since it was believed that Tier 1 Contractors would have an overview of the construction industry and that these individuals would therefore have a balanced understanding of the occurrence of error across the industry.

As would be expected in different sectors of the industry, different areas of work have the highest frequency of error. However, the root causes of error were found to be similar across the civil engineering and building sectors.

The strongest themes arising from the structured interviews were that the principal causes of error included:

- Poor planning, and in particular a failure to adequately rework the plan when things do not go to plan.
- Poor design (both by client side design teams and by designers working for trade contractors).
- A desire to “Do something”.
- Errors by the trades are rarely the result of a lack of technical ability. These errors are frequently a result of a lack of adequate planning by the individual of the particular task.

All of these items represent a failure to think in advance.

A similarly strong theme was that errors are often the result of a failure of communication of all types (written, drawn and verbal) and at all levels.

6.3. Review of the analysis using the Delphi Method

The experts were very experienced individuals who work across a broad range of the UK construction industry. The majority of the people interviewed worked for Tier 1 Contractors. This selection was intentional since it was believed that Tier 1 Contractors would have an overview of the construction industry and that these individuals would therefore have a balanced understanding of the occurrence of error across the industry.

There was little change in the results of the first and second round of the Delphi Method analysis. It is very unlikely that the results would have altered materially if further rounds of the analysis had been completed.

The differences in the rankings assigned by the experts from the Civil Engineering and Building sectors reflect the nature of the work in each sector.

6.4. Review of the online survey

The invitation to complete the online survey was circulated to professionals working in the UK Construction Industry, however we have limited information about the people who responded and the respondents may not be representative of the whole of the UK construction industry. For example it is possible to conceive of scenarios in which enthusiasm within one or two organisations would lead to skewed results. Therefore the survey results should not be considered definitive.

Of the 143 respondents around 70 answered each part of each of the two questions. There is a good balance between the building and civil engineering sectors.

The majority (63%) of the respondents to the online survey identified themselves as trade contractors.

To encourage participation the online survey was designed to be something that could be completed within a few minutes. The majority of the respondents to the online survey had probably not considered the occurrence of error in the construction industry in the same depth as the people we met during the structured interviews and the experts who participated in the Delphi Method analysis.

There was a small number of respondents who do not appear to have given the questions due consideration – for example all of the root causes of error have been assigned the same maximum weighting. However the majority of the respondents to the online survey do appear to have provided considered answers.

The principal themes that emerge from the comments are that planning and design need to improve and that one of the principal barriers to this is the late appointment of trade contractors.

6.5. Review of the comparison of the results of the Delphi Method and the online survey

Most significant areas by financial impact arising from errors

Civil engineering

The principal differences in the rankings assigned by the Delphi Method and the online survey are:

1. Mechanical systems (including BMS) were ranked as the 3rd most significant item by the Delphi Method analysis and as the 9th most significant item by the online survey. The discrepancy may indicate that the civil engineering experts in the Delphi Method analysis were influenced by the discussion of the impact of Mechanical systems (including BMS) in the building sector.

2. Piling work is ranked more highly in the online survey (3rd most significant area of work) than it was by the Delphi Method analysis (8th most significant area of work).

3. Damage to completed works is ranked more highly in the online survey (6th most significant area of work) than it was by the Delphi Method analysis (11th most significant area of work).

The differences in the rankings may be a result of the larger proportion of trade contractors in the online survey responses than there was among the Delphi Method experts.

The online survey results are broadly consistent with the other results of the Delphi Method analysis.

Building

The principal differences in the rankings assigned by the Delphi Method and the online survey are:

1. Mechanical systems (including BMS) were ranked as the most significant item by the Delphi Method analysis and as the 5th most significant item by the online survey.

2. Basement waterproofing is ranked more highly in the online survey (3rd most significant area of work) than it was by the Delphi Method analysis (7th most significant area of work).

The online survey results are broadly consistent with the other results of the Delphi Method analysis.

Across industry

There are substantial differences between the online survey rankings and the results of the Delphi Method analysis. However the apparently large discrepancies between the rankings are the result of small differences in the averages of the rankings assigned by the respondents: the apparently large discrepancies are a reflection of the fact that once the results of the Civil Engineering and Building sectors are combined there is little difference in the average rankings for the work areas between “Damage to completed elements” and “Electrical Systems”.

Therefore despite the apparent large discrepancies, the online survey results are in fact broadly consistent with the other results of the Delphi Method analysis.

Ranking of the root causes of error according to financial impact

Civil engineering

The principal differences in the rankings assigned by the Delphi Method and the online survey are:

1. Poor culture in relation to quality is ranked as the 3rd most significant item by the Delphi Method analysis and as the 10th most significant item by the online survey. The discrepancy is a result in small differences in the average weightings applied to several items.

2. Excessive commercial (financial and time) pressures is ranked as the 4th most significant item by the Delphi Method analysis and as the 10th most significant item by the online survey. The discrepancy is a result in small differences in the average weightings applied to several items.

3. Inadequate attention paid in the design to construction is ranked more highly in the online survey (the most significant area of work) than it was by the Delphi Method analysis (11th most significant area of work). The discrepancy is a result in small differences in the average weightings applied to several items in the online survey.

4. Deficient materials or components is ranked more highly in the online survey (7th most significant area of work) than it was by the Delphi Method analysis (12th most significant area of work). The discrepancy is a result in small differences in the average weightings applied to several items in the online survey.

The Delphi Method ranking of the remaining areas of work is broadly confirmed by the online survey results.

Building

The principal differences in the rankings assigned by the Delphi Method and the online survey are:

1. Poor culture in relation to quality is ranked as the 5th most significant item by the Delphi Method analysis and as the 11th most significant item by the online survey.

2. Late design changes are ranked more highly in the online survey (3rd most significant area of work) than it was by the Delphi Method analysis (9th most significant area of work).

The Delphi Method ranking of the remaining areas of work is broadly confirmed by the online survey results.

Across industry

The principal differences in the rankings assigned by the Delphi Method and the online survey are:

1. Poor culture in relation to quality is ranked as the 3rd most significant item in the Delphi Method analysis and as the 10th most significant item by the online survey. The discrepancy is a result in small differences in the average weightings applied to several items in the online survey.

2. Inadequate attention paid in the design to construction is ranked more highly the online survey (the most significant item) than it was by the Delphi Method analysis (the 6th most significant item). The discrepancy is a result in small differences in the average weightings applied to several items in the online survey.

3. Ineffective communication between team members is ranked more highly in the online survey (5^{th} most significant item) than it was by the Delphi Method analysis (9^{th} most significant item). The discrepancy is a result in small differences in the average weightings applied to several items in the online survey.

4. Inadequate trade skills is ranked more highly in the online survey (5^{th} most significant area of work) than it was by the Delphi Method analysis (9^{th} most significant area of work). The discrepancy is a result in small differences in the average weightings applied to several items in the online survey.

The Delphi Method ranking of the remaining areas of work is broadly confirmed by the online survey results.

Viewed as a whole the online line survey corroborates the result of the Delphi Method analysis.

6.6. An estimate of the total cost of error in the UK construction industry

Recent studies referred to in the desk study suggest that the direct cost of recorded error is around 5% of the total construction cost. This figure is consistent with the figures reported to us by Tier 1 Contractors. Our research suggests that the direct cost of error to Tier 2 Contractors and below may well be greater than 5%.

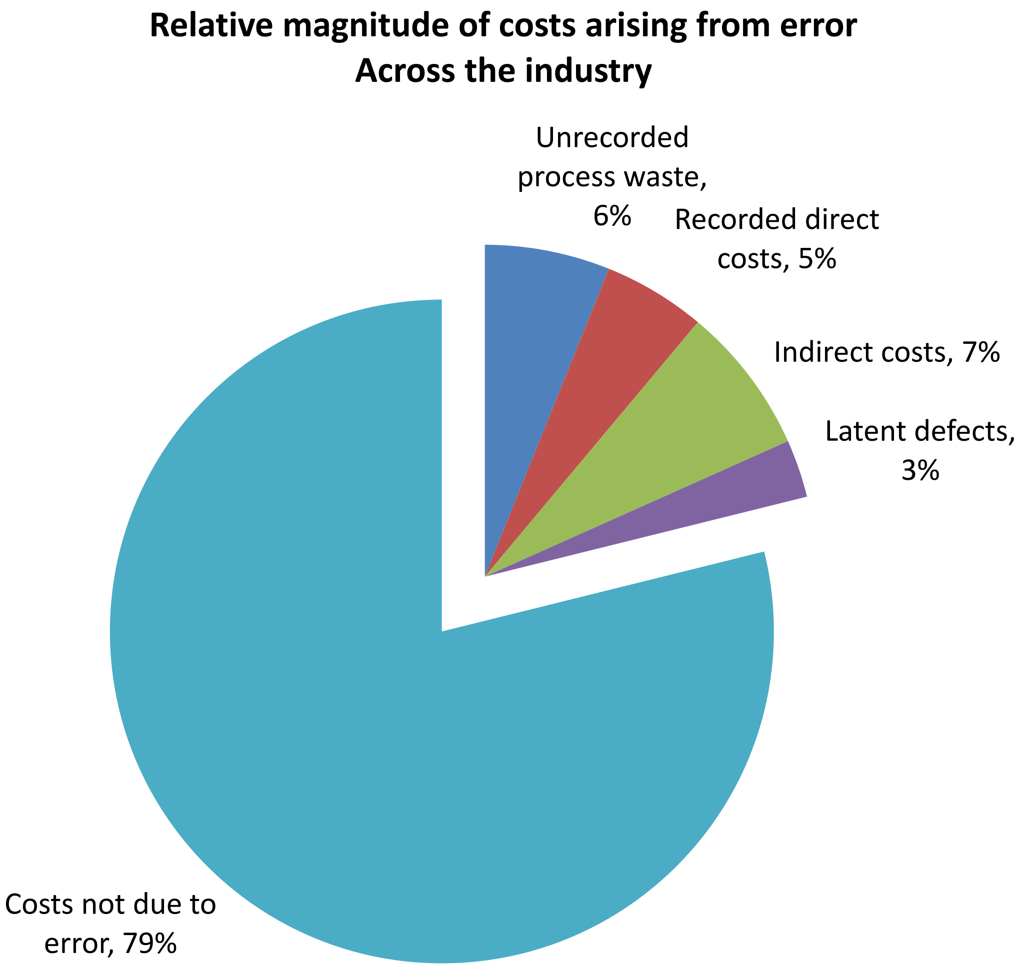
The Delphi Method analysis provided us with an estimate of the relative magnitude of costs arising from recorded direct costs (24%), indirect costs (34%), unrecorded process waste (29%) and latent defects (13%). If we assume that the direct cost of recorded error is around 5% the results of the Delphi analysis suggest the total cost of error to the UK construction industry is around 21% of the total spend.

		Spend as a proportion of the total cost of construction	
Spend arising from error	Recorded direct costs	5%	21%
	Indirect costs	7%	
	Unrecorded process waste	6%	
	Latent defects	3%	
Spend not arising from error			79%
	Total spend		100%

This figure suggests that there has been some improvement since the Egan report in 1998 which quoted a figure of 30% for the cost of rework in the USA, Scandinavia and the UK. The Delphi Method estimate of the total cost of error as around 21% of the total spend is also consistent with the work by Barber et al. (2000) who suggested that rework might be as high as 23% of contract value.

Love & Edwards (2004) showed that earlier work on rework costs reported values of between 3 and 15 per cent of an individual project's contract value; while in 2015 Simpeh et al. (2015) found that the total rework costs range from 0% to 75%.

In summary: improvements have been made in the seventeen years since the Egan report, however scope remains to make substantial further reductions in the cost of error.



6.7. Where the cost of error is carried

Following this phase of the Get It Right Initiative we believe that majority of the initial cost of error is incurred by Tier 2 Contractors and this cost is often invisible both to Tier 1 Contractors and to end Clients. While the initial costs are incurred by Tier 2 Contractors, that cost is included in procurement costs: although the cost of error is often invisible to Clients the cost is passed on to Clients.

Most companies recognise that there is a cost issue with errors but it appears that none is clear as to the full extent of those costs. The structure of the supply chain and the business models of those involved make it difficult for any single organisation to develop a comprehensive understanding of the costs of error in the construction process.

6.8. The areas of work in which the financial impact of error is most significant

The areas of work where the financial impact of error is the most significant are:

- Concrete
- Mechanical and Electrical
- Facades

However, there is potential to reduce the cost of error across the industry particularly if we concentrate on the root causes as discussed below.

6.9. The financially most significant root causes of error

The main reasons for error lie in the areas of poor planning, changes, poor communication and incorrect design at all levels. All of these can be summarised as action commencing before there is sufficient understanding of the requirements.

This failure is perhaps most clearly demonstrated in the "Get It Done" attitude that is commonplace and admired in our industry and which means that poor decisions are frequently made.

Effective communication delivers understanding and involves relationships as much as clarity of expression in drawings, documents and words. Ineffective working relationships are a significant contributing factor to failures of communication and the errors that result.

Achieving an understanding of the requirements takes time. Rushed procurement, rushed design and rushed planning all compromise effective understanding and contribute to the occurrence of error.

Some events are outside the control of the project team: there are deviations from even the best laid plans. A plan must be resilient, and it must be maintained. There is abundant evidence from this phase of the Get It Right Initiative that as an industry we fall short on this.

There are many specialisms in the industry with the consequence that many people work in silos. This causes errors in implementation. As an example designers need to understand the consequences to the procurement process of what they are designing whilst those carrying out the procurement need to understand the importance of not deviating from a specification.

Current design, procurement and construction processes sometimes generate perverse outcomes (e.g. ignoring an error in the design documentation knowing that there will be scope to make a claim later)

6.10. Towards a reduction in the cost of error in the UK construction industry

Reduction of error presents a major opportunity for achieving a reduction of cost to the UK construction industry.

The majority of the initial cost of error is incurred by Tier 2 Contractors. The Tier 1 Contractors can take steps to reduce the cost of error to Tier 2 Contractors. The improvements that can be achieved by the Tier 2 Contractors will be limited without the active assistance of Tier 1 contractors. It appears that there is sometimes little incentive for the Tier 1 Contractors to act to reduce the cost of error to the Tier 2 Contractors.

Although there are arguments which say that different forms of contract engender better or worse approaches to the elimination of error we found little evidence that the form of contract is a key cause of error. Perhaps the key contribution would be a contract that delivers effective working relationships between individuals.

More important than the form of contract is that organisations must have the right culture to encourage the elimination of error. Currently we put an over-reliance on contractual communications and formal communications. We need to focus on forming effective relationships both at an individual and organisational level. Time is a crucial factor and the dominance of the programme has a negative impact on quality.

The industry has a reputation for getting on with things to the detriment of thinking things through to make sure that we have the right solutions. The Get It Done attitude that is commonplace and admired in our industry means that poor decisions are frequently made. At all levels people need to be educated so that they stand back and think before taking action.

Change always creates the risk of error. It is important for organisations to try to minimise change once the process has started. However, even if we control the controllable we will still have to deal with events and circumstances over which we have no control. As an industry we need to get closer to the military model where it is recognised that things will not go according to plan and to replan accordingly. This is a crucial area of eliminating error. We need to control the controllable and replan the uncontrolled.

It is difficult for a single organisation to make sustained progress in reducing errors within their own work because the root causes often sit outside their direct control.

There has been criticism of the Construction Industry suggesting that if it followed automotive industry practices it would be much more efficient and that there would be less error. Construction is different to production industries such as the automotive industry. This does not mean that we should not adopt techniques from the automotive industry but we do need to recognise that the industries are very different.

In terms of looking ahead we need to change our focus from managing the consequences of error to eliminating the causes of error.

Despite many of the issues of poor practice that we have highlighted it must be said that there are some outstanding examples of good practice. There are organisations where the approach to eliminating error is lead from the top of the organisation. There is no doubt that the level of quality achieved by these organisations is several orders of magnitude higher than the others. The challenge is to bring all of the less well performing organisations up to the same level.

7. Recommendations

Our recommendations are presented in the Get It Right Initiative report “Strategy for Change”, November 2015.

Appendix A – On Line Survey

This appendix includes additional information relating to the online survey. The appendix includes:

1. The survey questions that respondents were asked to complete.

2. The results of the online survey presented to identify the differences in the responses provided by Main Contractors and Trade Contractors in each of the building and civil engineering sectors.

1. The survey questions

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It is estimated that each year the construction industry wastes between 3% and 10% of its circa £100 billon turnover in correcting errors and possibly more. To meet this challenge the Get It Right Initiative Group is carrying out a research project into errors in construction and their causes. The objective of the study is to identify the root causes of errors and develop initiatives to save costs by eliminating errors at all levels of the construction process. The output of the report will be disseminated throughout the industry so that the lessons learned can be adopted by all as appropriate. The group is made up of a significant number of Clients, Main Contractors and specialist contractors and the study is funded jointly by these Companies and the CITB.

Please note that all responses are confidential and we will ensure that your answers cannot be traced back to the original respondent.

Many thanks for your help.

The Get It Right Initiative Group

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1. My organisation is primarily:

A trade contractor
A main contractor
A designer (or consultant supporting the design team)
A client or client's representative

2. The work of my organisation, or that part of it that I represent, relates primarily to:

Civil Engineering (Rail, Roads, Bridges, Water Industry etc.)
Buildings

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Error

3. A poll amongst the Get It Right Initiative Group has suggested that the errors in the following areas of work have the most serious financial impact to projects. Please drag and drop the items to rank them. The area of work in which error with the highest economic impact should be ranked as 1 with the lowest economic impact as 13.

Basement Waterproofing

Concrete Works

Damage to completed works

Drainage

Electrical Systems

Facades / Cladding

Finishes

Mechanical Systems (including BMS)

Piling

Roads and Pavements

Roofing

Setting Out

Steelwork coatings

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Reasons

4. The factors in the table below all have an impact on the construction process and are all known to cause error. Please allocate a score from 1 (low impact) to 10 (high impact) to each of these factors.

Contractual arrangements

Deficient materials or components

Excessive commercial (financial and time) pressures

Inadequate attention paid in the design to construction

Inadequate planning (from task through to project level)

Inadequate professional skills (contract & sub-contract management)

Inadequate supervisory skills

Inadequate trade skills

Ineffective communication between team members

Ineffective relationships between team members

Information Overload

Late design changes

Poor culture in relation to quality

Poor interface management and design

Poor site conditions and access

Poorly communicated design information

Poorly coordinated and incorrect design information

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Comments

5. Are there any comments that you would like to add?

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Thank you for completing the survey.

Survey created by the Get It Right Initiative Group.

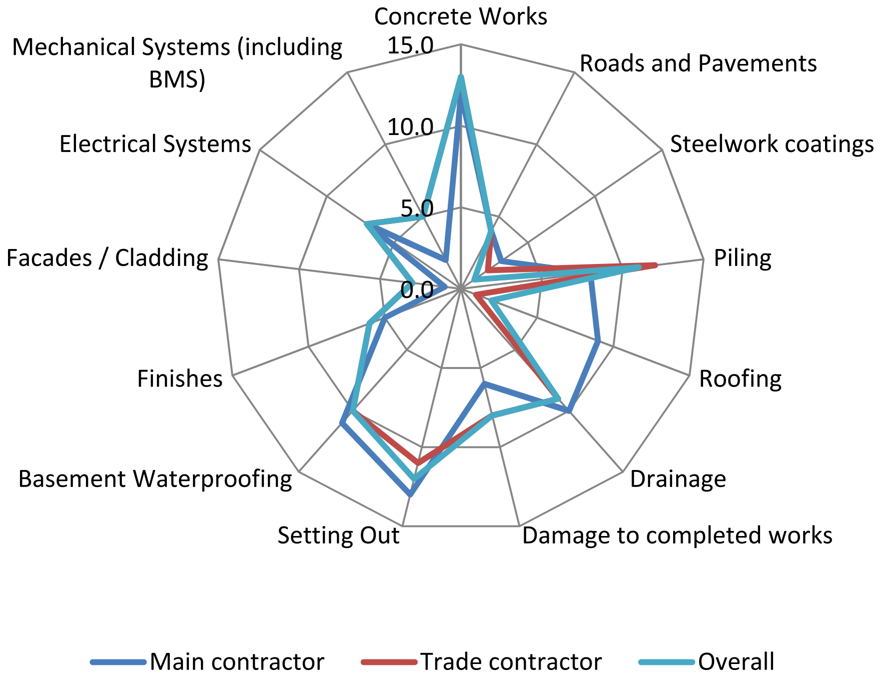
2. The results for Main Contractors and Trade Contractors

The charts below plot the survey results split by the responses from the main contractors and trade contractors. Relatively small numbers of clients and designers responded to the survey, therefore the results for clients and designers have not been presented separately. Note that the results from clients and designers are included in the category “Overall”.

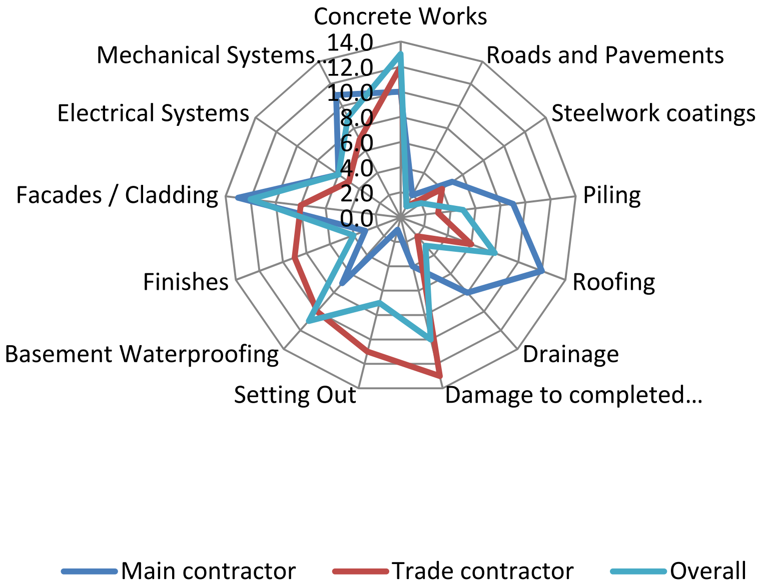
The table below identifies the chart number for each of the sets of results.

	Error Areas		Root causes	
	Ranking	Averages	Ranking	Averages
Civil Engineering Sector (breakdown by firm type)	A1	A4	A7	A10
Building Sector (breakdown by firm type)	A2	A5	A8	A11
Overall (breakdown by firm type)	A3	A6	A9	A12

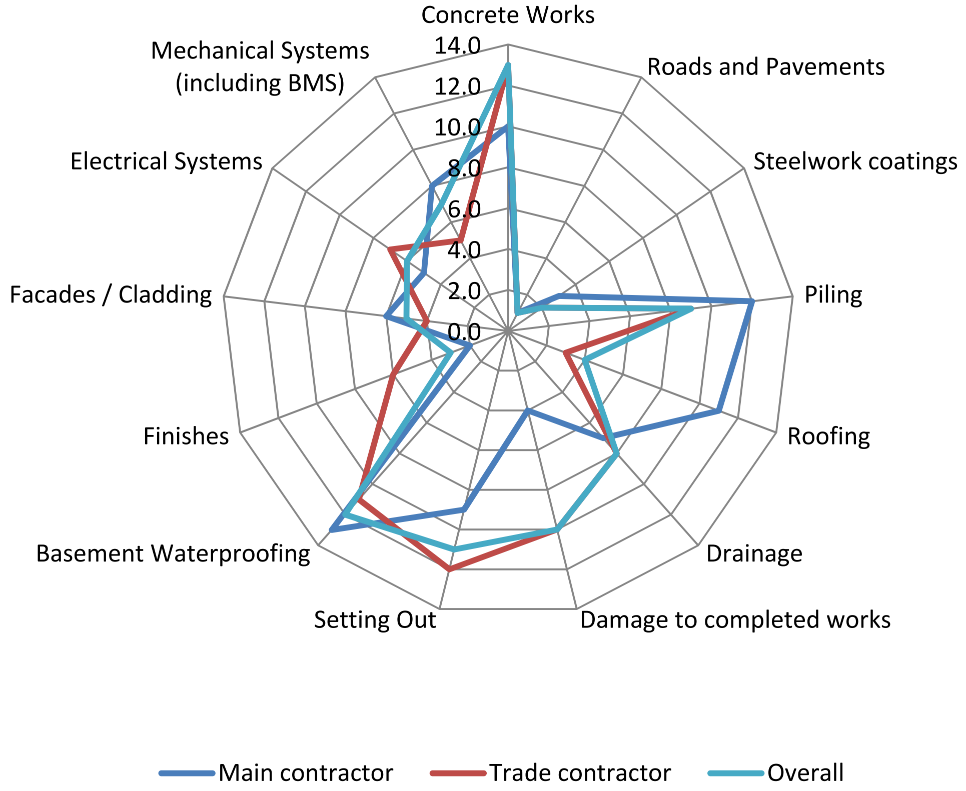
A1. SURVEY: Error Areas Ranking - Civil Engineering Sector (high values are more signficant)



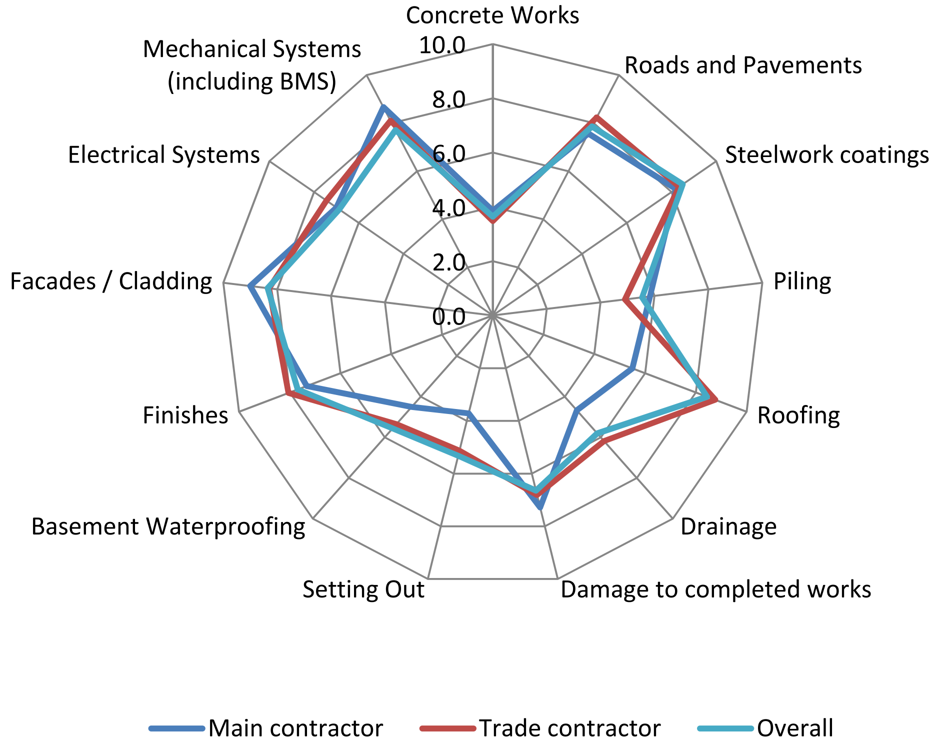
A2. SURVEY: Error Areas Ranking - Building Sector (high values are more signficant)



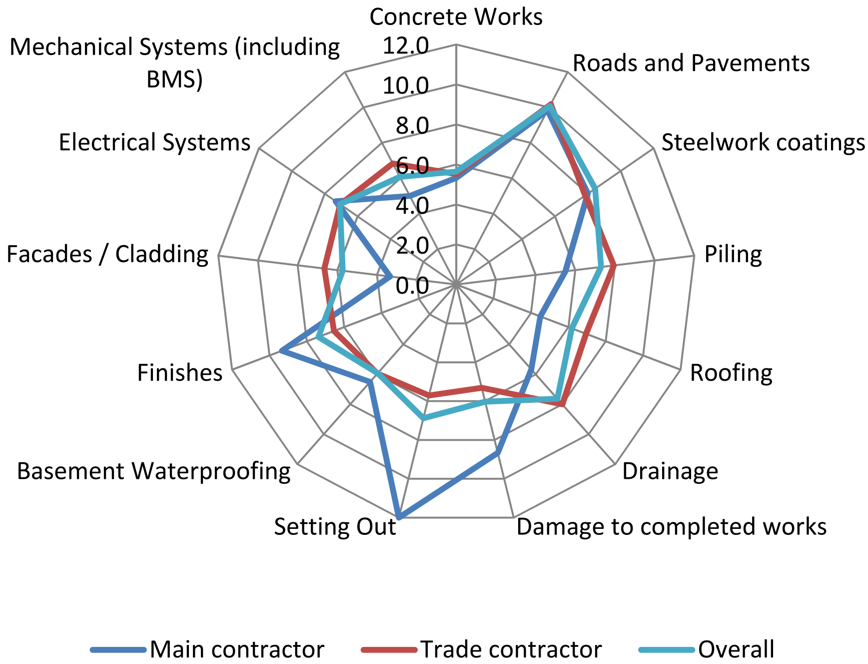
A7. SURVEY: Error Areas Ranking - Whole Construction Industry (high values are more signficant)



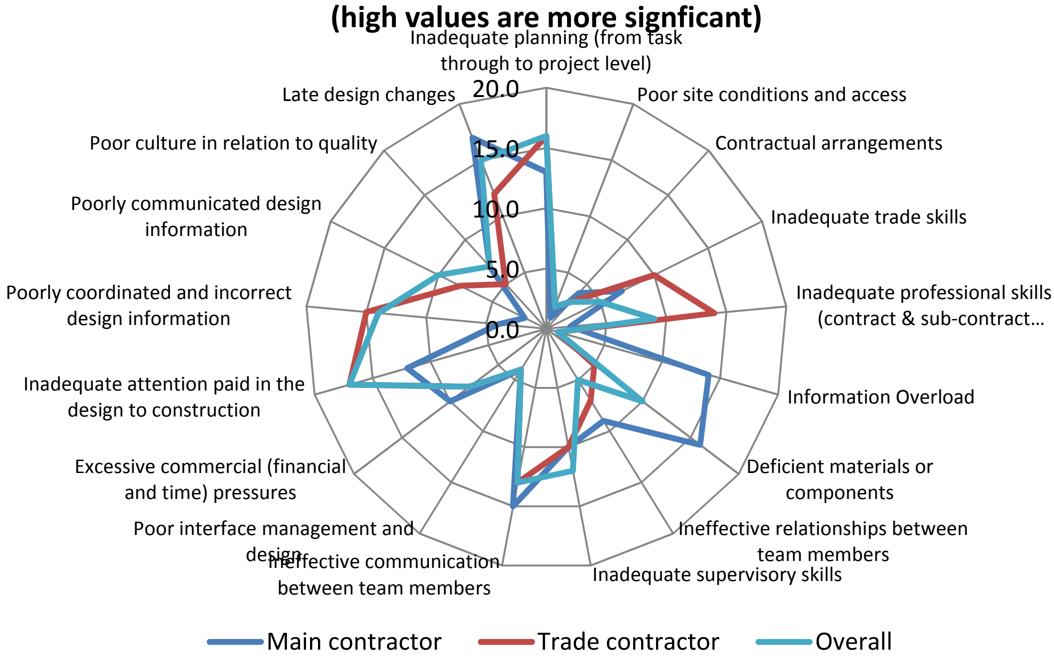
A4. SURVEY: Error Areas Averages - Civil Engineering Sector (low values are more signficant)



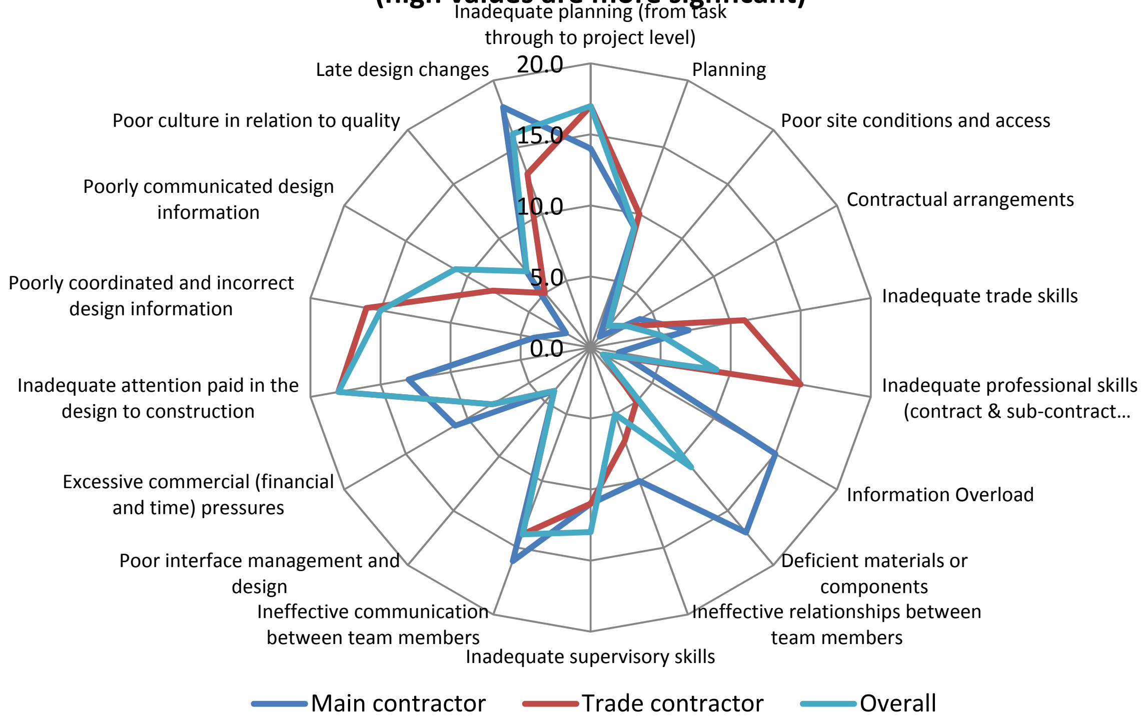
A5. SURVEY: Error Areas Averages - Building Sector (low values are more signficant)



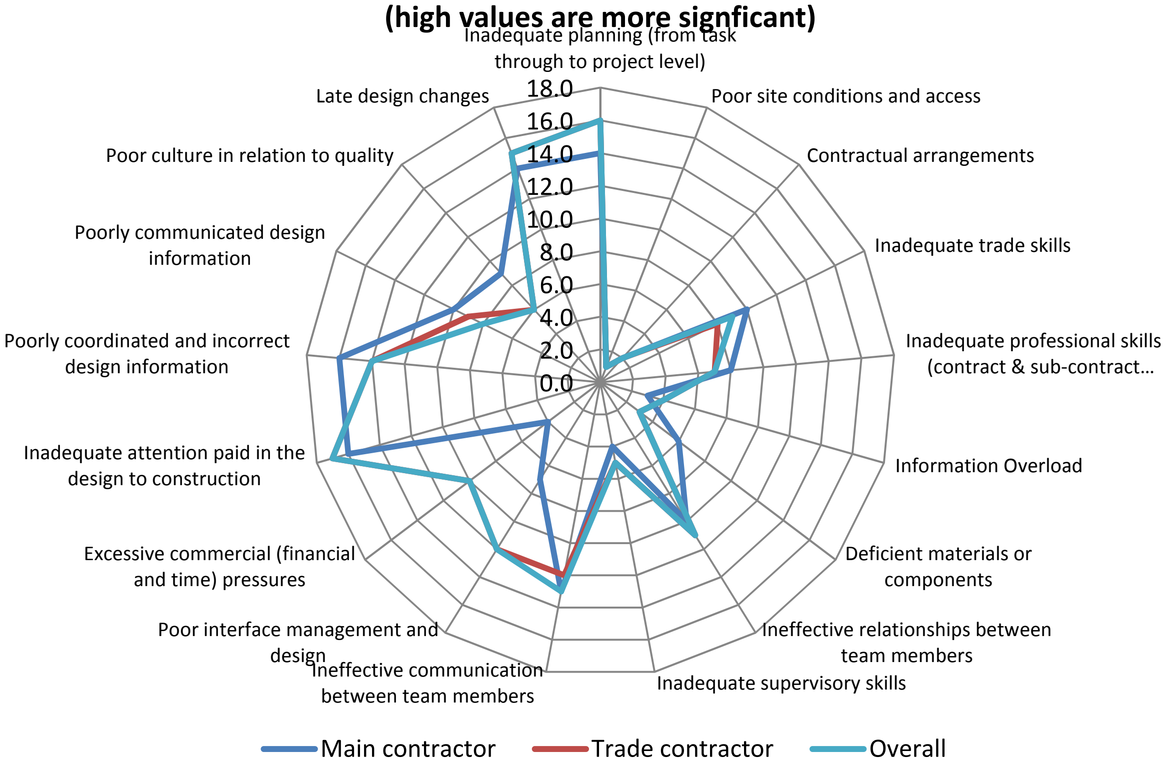
A6. SURVEY: Root Causes - Ranking - Civil Engineering Sector (high values are more signficant)



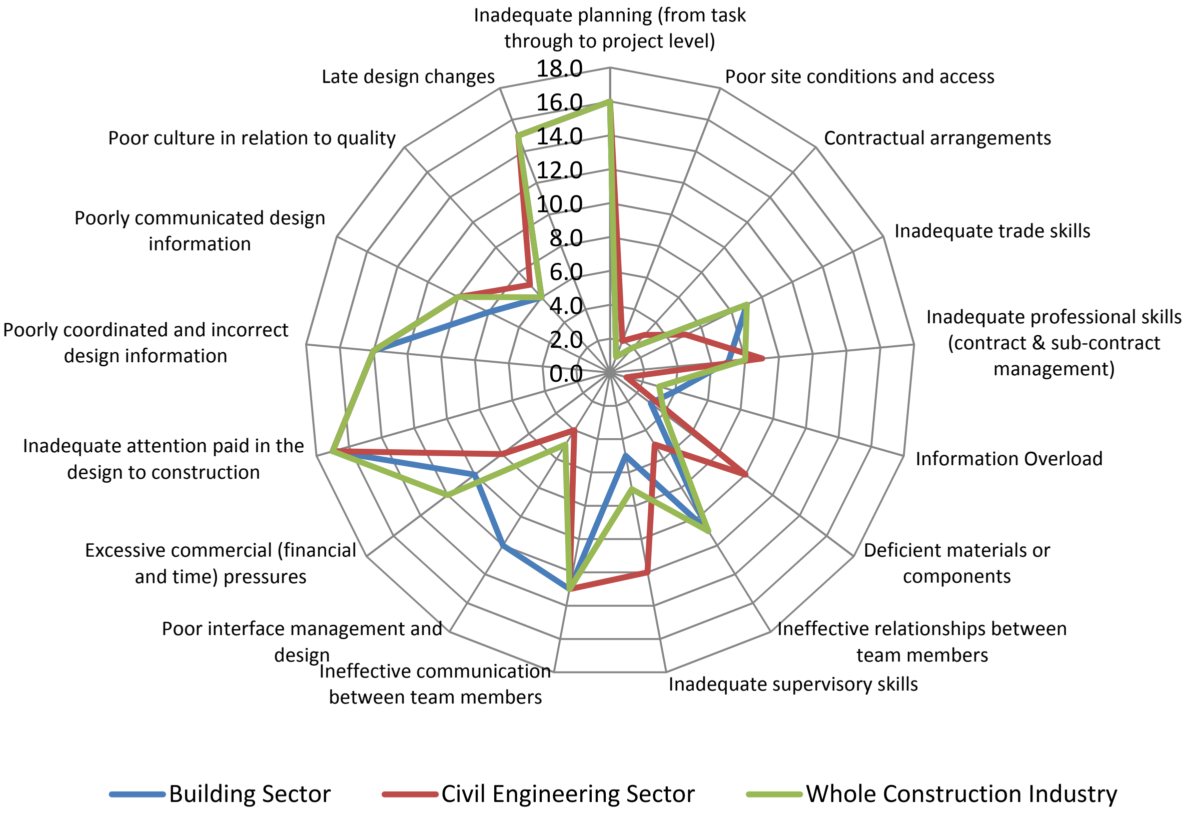
A7. SURVEY: Root Causes - Ranking - Civil Engineering Sector (high values are more signficant)



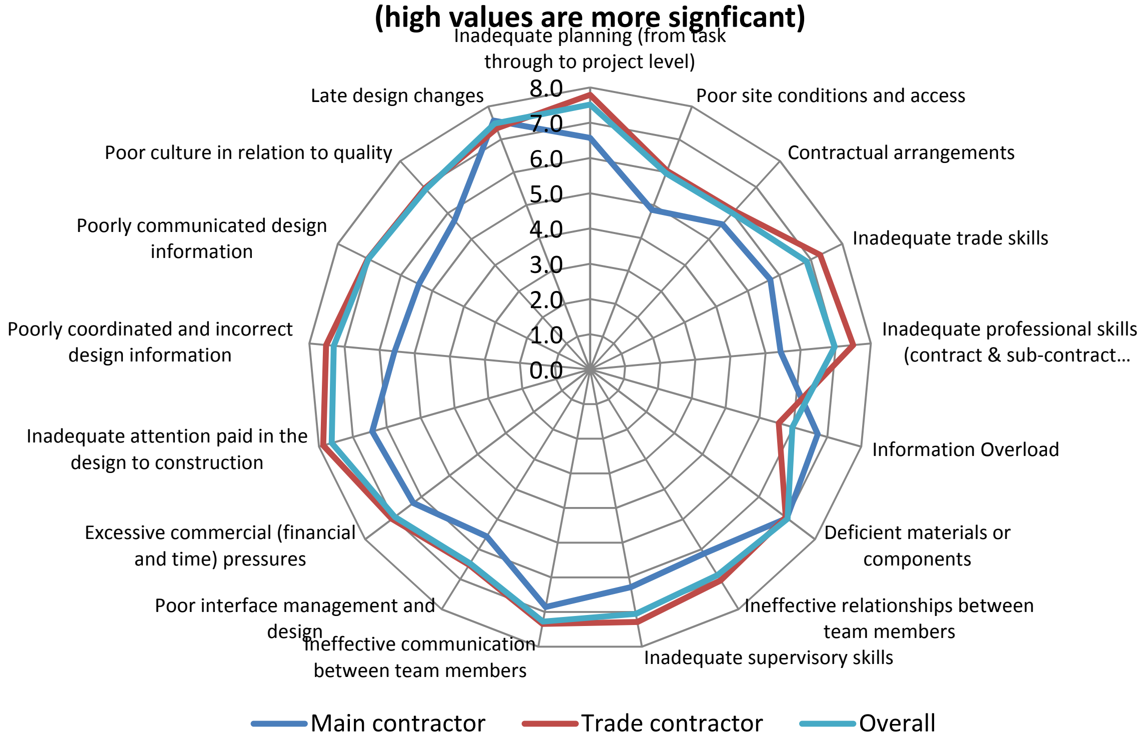
A8. SURVEY: Root Causes - Ranking - Building Sector (high values are more signficant)

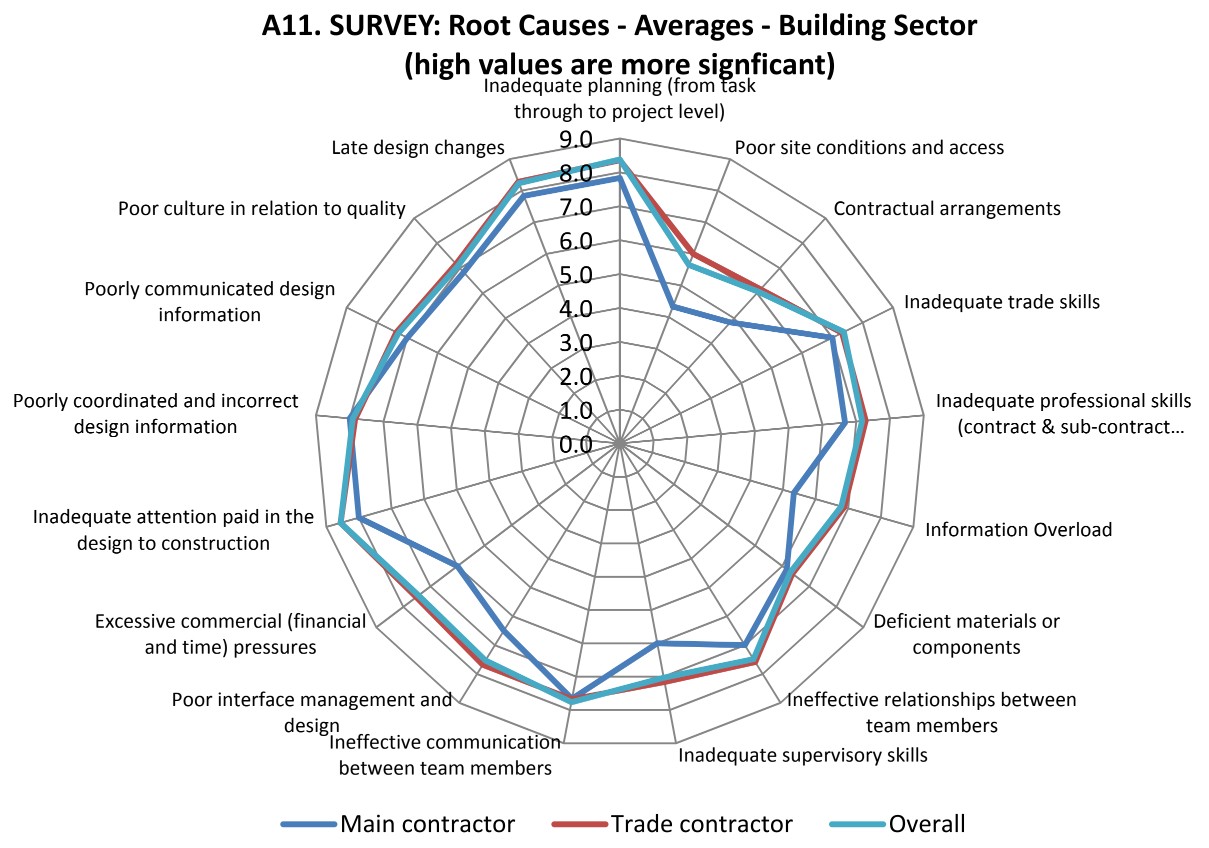


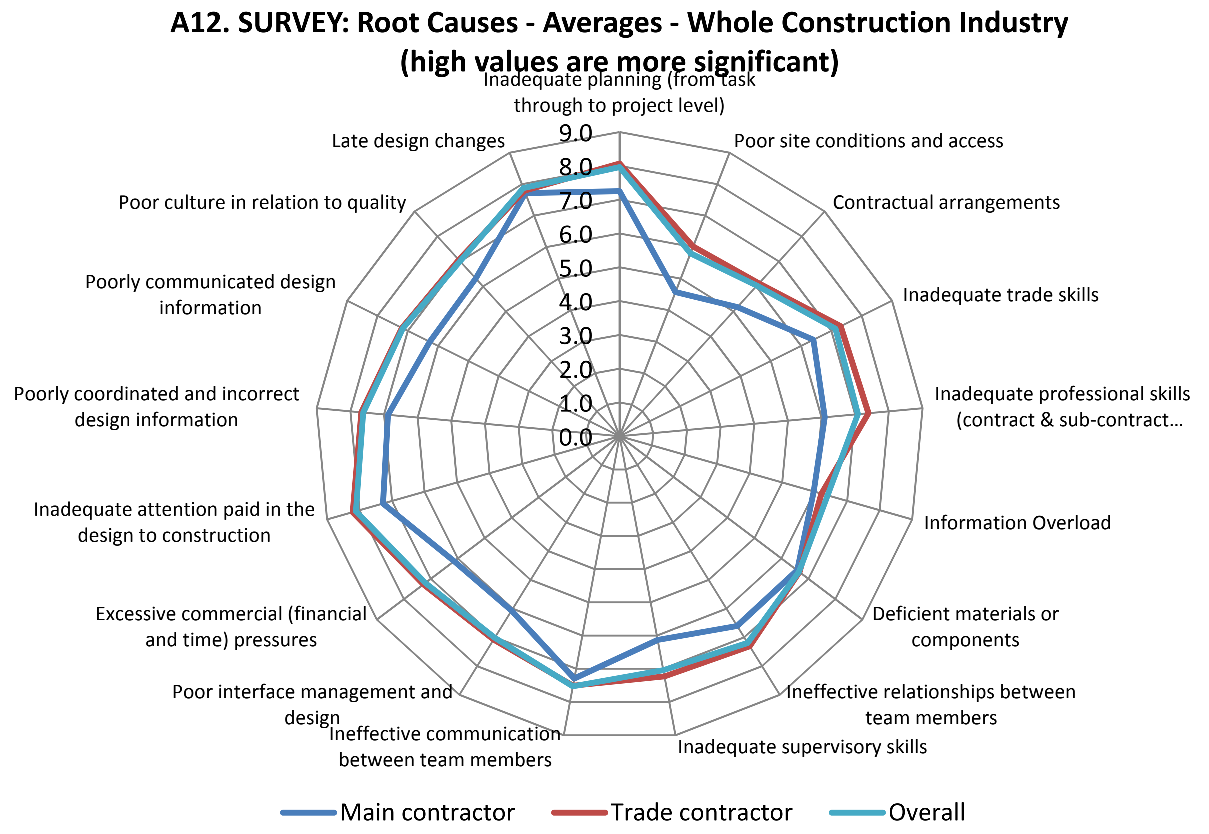
A9. SURVEY: Root Causes - Ranking - Whole Industry (high values are more significant)



A10. SURVEY: Root Causes - Averages - Civil Engineering Sector (high values are more signficant)




A11. SURVEY: Root Causes - Averages - Building Sector
(high values are more signficant)
Inadequate planning (from task through to project level)
Poor site conditions and access
Contractual arrangements
Inadequate trade skills
Inadequate professional skills (contract & sub-contract...
Information Overload
Deficient materials or components
Ineffective relationships between team members
Inadequate supervisory skills
Ineffective communication between team members
Poor interface management and design
Excessive commercial (financial and time) pressures
Inadequate attention paid in the design to construction
Poorly coordinated and incorrect design information
Poorly communicated design information
Poor culture in relation to quality
Late design changes
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Main contractor
Trade contractor
Overall


A12. SURVEY: Root Causes - Averages - Whole Construction Industry
(high values are more significant)
Inadequate planning (from task through to project level)
Poor site conditions and access
Contractual arrangements
Inadequate trade skills
Inadequate professional skills (contract & sub-contract...
Information Overload
Deficient materials or components
Ineffective relationships between team members
Inadequate supervisory skills
Ineffective communication between team members
Poor interface management and design
Excessive commercial (financial and time) pressures
Inadequate attention paid in the design to construction
Poorly coordinated and incorrect design information
Poorly communicated design information
Poor culture in relation to quality
Late design changes
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Main contractor
Trade contractor
Overall

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