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Authors: Robby Soetanto, Andrew R.J. Dainty, Chris I.
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Highlight

- Presents a systematic method for analysing complex scenario development outcomes.
- The method was employed in several workshops addressing construction industry skills.
- A merged collective map provides a more holistic overview of the pertinent issues.
- The method facilitates discussion amongst key stakeholders regarding skills scenarios.
- The method could be applied to other areas requiring longer range planning.

Accepted Manuscript

Unravelling the complexity of collective mental models: a method for developing and analysing scenarios in multi-organisational contexts

Robby Soetanto^{1*}, Andrew R.J. Dainty², Chris I. Goodier³ and Simon A. Austin⁴

¹ Department of Built Environment, Coventry University, Priory Street, Coventry, CV1 5FB, UK; Robby.Soetanto@coventry.ac.uk

² Department of Civil and Building Engineering, Loughborough University, Leicestershire, LE11 3TU, UK; A.R.J.Dainty@lboro.ac.uk

³ Department of Civil and Building Engineering, Loughborough University, Leicestershire, LE11 3TU, UK; c.i.goodier@lboro.ac.uk

⁴ Department of Civil and Building Engineering, Loughborough University, Leicestershire, LE11 3TU, UK; S.A.Austin@lboro.ac.uk

* Corresponding author, phone: +44(0)24 7679 5189, fax: +44(0)24 7688 8296, e-mail address: Robby.Soetanto@coventry.ac.uk, postal address: Department of Built Environment, Coventry University, Priory Street, Coventry, CV1 5FB, UK

Abstract

In multi-organisational contexts, scenario building has been used to engage stakeholders in a critical discussion on issues of mutual importance, and to gain their support with regards to possible future responses. A review of existing literature suggests that much has been written regarding the process of scenario development and the benefits of the process, but the detailed analysis of scenario building outcomes, which encompass a large number of issues and their complex interconnections, has not been made explicit for studying and enhancing understanding of a complex societal problem. This paper presents a systematic method for analysing such complex outcomes in order to facilitate reflective thinking on important issues within the wider context for policy development. The method was employed in a series of participative scenario development workshops, which yielded several causal maps around the theme of construction industry skills. A collective map merging the individual subject-specific causal maps was created to help provide a more holistic overview of the pertinent issues surrounding the construction skills debate. The analysis of this collective map promotes a better understanding of the issue in the wider context, the consequence of possible future events and actions, and of the pre-requisition required for certain events/desired outcomes to take place. The main benefit that could be derived from the method is the opportunity to help facilitate and encourage debate and discussion amongst key stakeholders regarding scenario theme, in this case skills improvement within construction. Due to its flexibility and adaptability, the method could potentially be applied to other areas requiring longer range planning and which contain multiple stakeholder perspectives.

Keywords: construction skills, scenario planning, cognitive mapping, multi-stakeholders

1. Introduction

In the futures field, scenarios mean different thing for different users, and may serve different purposes [1]. For exploratory studies, a scenario is often seen as an image of a future environment within which an entity may have to live or operate. Scenario development is not an exact science. It is not to predict the future, but to explore several plausible future environments with the purpose of extending the sphere of thinking of the participants in process [2,3]. The main benefit is perceived not only from the product (i.e. scenarios *per se*), but the process in which participants can appreciate plausible futures which inform actions and strategies [4]. Engaging the stakeholders (e.g. in workshops) is seen as a mean to encourage their support to the scenarios and possible future responses. It is context-dependent process in which the interaction and negotiation during the development, and subsequent interpretation and enactment of the scenarios very much reside within the mind of individuals involved in the process. Chermack et al. [5] refer the process of scenario development to organisational learning. As the process is often perceived more important than the product, many scholars have written about the process and methodology of developing scenarios (for examples [2,6,7,8,9,10,11]) and the benefits of the process (for examples [12,13]), but less on the content and nature of the scenarios themselves [4]. Moreover, there is a dearth of literature reporting on the analysis of scenarios developed in a

1 multi-organisational context in order to address an issue of mutual importance. One of the
2 reasons is the oversimplification of assumptions in the process of scenario planning, which
3 otherwise is likely to yield complex outcomes and multiple interpretations of those outcomes
4 [14]. Chairns et al. [15] described scenario development in a multi-organisation context, which
5 yielded numerous 'driving forces' of the future. However, the analysis of these 'driving forces'
6 and their complex interconnections have not been made explicit. This paper is intended to
7 contribute to this gap of knowledge and literature by developing a systematic method for
8 analysing such complex outcomes to facilitate reflective thinking on important issues within
9 the wider context for policy development.

10 To reflect the uncertainty inherent in the future, scenario development should yield multiple
11 scenarios, commonly between two and four. One approach is the scenario-axes technique
12 which is often recommended as a useful and straightforward tool to construct scenarios in a
13 coherent and systematic way [16]. This approach yields four scenarios within four quadrants
14 of two main axes which represent the most influential high-level drivers of the future (for
15 examples [17,18]). Then, each is illustrated by an imaginative narration of a future
16 environment with the intention of stimulating thought. One common step of the development
17 process is the identification of 'issues' (also called 'drivers' which are precedence of 'trends')
18 which are perceived as the underlying causes of future phenomenon of interest within an
19 environment of a particular industry sector. Börjeson et al. [1] describes this process as the
20 generation of ideas phase of exploratory scenario development. Further, the two most
21 important drivers are often used to form the dimensions of the scenario-axes approach.
22 Despite their utility to present snap-shot images of the future, most scenarios do not make
23 explicit the connection between present and future [19]. This connection can help establish a
24 pathway of interconnected sequences of events from now to the envisaged future goal.
25 Arguably, developing this pathway enhances participant understanding, support and
26 confidence in the scenarios. Ultimately, it will help individual entities to shape (and reshape)
27 their strategic plan and future actions.

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29 The issues are not independent, but reside within a complex interconnected web of cause-
30 and-effect relationships. Due to their significance in shaping the future, understanding of
31 these interconnections can sometimes be more important than understanding individual
32 issues themselves. However, evidence suggests that participants of scenario development
33 workshops would seem to be very fluent when identifying issues, but are not very comfortable
34 when determining interconnections between these issues [11]. Perhaps, there is a greater
35 intellectual challenge in establishing the interconnections and negotiating differing
36 perspectives (with possible conflicts) between participants of the workshop. This challenge is
37 further reinforced by a requirement to connect the present situation to long-term future goals
38 [20].
39

40 In this paper we develop a method for developing and analysing scenarios as manifested in a
41 complex network of the interconnected issues around the issue of skills shortages in
42 construction. This topic area provides an ideal 'test bed' for refining new methods of
43 combining the perspectives of multiple participants who bring differing perspectives to a
44 complex and multi-faceted issue. The challenge within this research was to establish a
45 coherent connection between the present and the future via a series of interactive workshops
46 which was not only intended to generate ideas, but also to integrate them for a greater
47 understanding of plausible futures. It was not the intention to develop envisioned futures
48 regarding skills shortages by way of resultant scenario or scenarios from the analysis, nor to
49 formulate accurate labour market forecasts. Rather, the aim was to move beyond the
50 constraints of existing forecasting models and to consider a much longer range view up to 20
51 years, and to stimulate a dialogue amongst key stakeholders which illuminates the
52 significance of greater understanding of the interconnectivity of the principal supply and
53 demand factors and the influence of institutional and social structures which support them.
54 Generating these types of insights for policy planning is necessarily a multiple stakeholder
55 exercise [14]. As such, establishing a way to coalesce the perspectives of a multiplicity of
56 different actors and to combine these in a robust, and yet intelligible format, represented the
57 core challenge of this research. The approach developed could have resonances well beyond
58 the present study to a variety of other multi-stakeholder futures workshops.
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2. Research context: the UK construction labour market

1 The research from which this paper is described explored possible futures for the UK
2 construction sector, especially in relation to the factors which influence the competitiveness of
3 the firms that operate within it. Construction is a highly competitive sector that is often
4 characterised by short-term thinking and frequently lacking of long-term strategic planning.
5 Managers of small firms tend to be preoccupied by daily operation of the business [21].
6 Research on strategic planning within the sector has revealed that some firms do not do any
7 long term planning and others planned only for a short-term future of 2-3 years [22]. Given the
8 absence of strategic planning, perhaps it is not surprising that the skills shortage continues to
9 be an enduring problem and is hampering the progress within the sector (see [23]). Indeed,
10 Forde and MacKenzie [24] have revealed that construction has a high concentration of skills
11 shortages relative to other sectors and, despite the initiatives for skills reproduction at sectoral
12 level (for example [25]), skills policy has seemingly done little to ensure a steady supply or to
13 secure the long-term sustainability of the sector skills base.

14
15 The convenience of migrant labour as a 'short-term fix' may reinforce the reluctance of
16 employers and government to address deficiencies in the industry's vocational education and
17 training structure [26]. This is therefore symptomatic of the acute need for more informed and
18 joined-up policy measures, which must be enacted so as to involve a broad cross section of
19 stakeholders if they are to be effective in addressing ingrained deficiencies in the skills
20 infrastructure [23]. Long-range construction skills planning is highly problematic given
21 fluctuating demand patterns, nuanced differences in demand in different geographic regions
22 and uncertainties in the unfolding impact of technological and process innovations. However,
23 given the scale of the challenge, effective policies need to be enacted well in advance of the
24 manifestation of the need. For example, encouraging trainees new to the sector demands a
25 recruitment campaign in time to influence school leavers to take up apprenticeships, and for
26 employers to be encouraged to engage in specific construction skills training. For such
27 workers to be up to productive capacity when required, they must be engaged many years
28 earlier. This requires a new skills planning paradigm, and one able to cope with the
29 interconnected nature of skills influences superbly illustrated by Clarke [27], who reveals how
30 social and institutional structures perpetuate the low skills equilibrium. It is arguably these
31 interconnected factors which must be better understood and addressed if a more sustainable
32 construction sector is to be achieved. Addressing skills shortage requires a concerted effort
33 from the key stakeholders who need to align their perceived thinking of the current situation,
34 influencing issues and to develop a consensus of pathways to preferred future.

3. Future studies in construction

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37 The significant body of literature on futures studies generally look ahead or envision what the
38 future may look like, but do not necessarily aim to predict what will happen. They are
39 frequently considered an early warning system, a way for people and businesses to visualise
40 the future some years ahead (usually 10 to 20 years) [28]. They are often produced to
41 promote forward-thinking within companies in particular. As a precursor to the work described
42 later in this paper, fifteen recent construction futures reports [28,29,30,31,32,33,34,35,36,
43 37,38,39,40,41,42] were reviewed to explore their substantive content. Each offers different
44 perspectives on envisioned futures ranging from the deliberately extreme to those which can
45 be effectively extrapolated from existing trends, although they rarely conflate different
46 perspectives or seek to blend different types of futures. The methodologies range from
47 individual speculative narratives, to consensus building workshops and Delphi-based
48 questionnaire surveys.

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51 Within the 'skills' theme, the reports generally suggested that the skills shortage (both at
52 professional and operative levels) would seem to continue in the foreseeable future. They
53 also realised the growing need for more training and for upgrading the existing skills base.
54 Construction professionals will need to acquire different set of skills requirements for the
55 future. In particular, future professionals will need to be more flexible, multi-skilled and able to
56 maintain appropriate balance between 'hard' technical and 'soft' skills, such as deal making,
57 client-facing, relationship management skills. Growing competition and uncertainty would
58 increase the popularity of shorter-term contracts. The workforce will be more empowered and
59 increasingly mobile to capture opportunity for better job and promotion. At operative level,
60 craft labour will be increasingly rare.

1 Although these reports identify a range of issues that might affect construction, arguably they
2 fail to address the complexities and uncertainties of both the present and the future, or to
3 explore the interconnections between global, local, construction-specific and more wide-
4 spread issues [19]. In addition, they tend to be written from a particular stakeholder
5 perspective, which in turn will determine whether an envisioned future is positive or negative.
6 For example, the use of technology (e.g. information and communication technology) will de-
7 skill the work of the professions, but at the same time, it will help to reduce accidents and
8 improve welfare of the workforce. Thus, understanding the interconnectivities is crucial for
9 generating a better understanding of possible futures and for building dynamic capabilities to
10 proactively respond to the potential challenges ahead. Thus, it would seem that these studies
11 have failed to address a crucial failing of past research on construction skills, which although
12 they reveal a large number of highly interconnected issues [23,43,44], have largely failed to
13 make these interdependencies sufficiently explicit for a more informed understanding.
14

15 **4. Overview of the method for informing future skills policy planning**

16 Given the potentially large number of variables which play out at (and between) various levels
17 of resolution (i.e. the individual, the firm, the region, the industry etc.), a visual representation
18 of possible interconnections is essential for supporting stakeholders in envisaging the ways in
19 which influences on the labour market could be linked together. Given the multiple contexts
20 within which skills are reproduced, these events may turn out to be less important than the
21 connections between them. Thus, to be effective, users of the proposed method must be able
22 to assess the implications of particular intervention strategies, together with their 'knock-on'
23 effects, to other interconnected factors.
24

25 Given this visual requirement, a scenario development process was developed for the
26 research incorporating multi-stakeholder perspective using causal mapping techniques (see
27 [11] for a detailed description of this process). This was deployed at a series of workshops in
28 which stakeholders were asked to initially consider the interrelationship of a range of
29 influential factors. The research therefore addresses one of the criticisms of much futures
30 work in the construction sector of failing to build upon the previous studies [31]. In this
31 research, the idea was to build from other futures and foresight work to identify future issues
32 which should be taken into account when planning skills policy measures and to supplement
33 these with stakeholder opinion on the skills climate. The scenarios derived from the process
34 were digitised using Decision Explorer™ software and then merged to produce a collective
35 causal maps. Several tools within the software were then used to identify most important
36 issues from the map and draw clusters around these issues. The use of this software is by no
37 means novel, although its application in the subject of construction skills problem in multi-
38 organisation context does not exist in the literature. In this research, the software is a useful
39 tool within a systematic method for analysing complex outcomes of scenario building
40 workshops.
41

42 In contrast with many futures methods which have an organisational focus, the research
43 challenge here was to connect the perspectives of multiple stakeholders within a holistic
44 analysis of labour market influences. In the next sections, several lessons learnt from the
45 process of generating, integrating and analysing the scenarios are explained, alongside the
46 possible use of the emerging resultant scenario in informing considerations for the
47 development of long-range skills planning policy.
48

49 **5. Scenario development process**

50 The detailed steps in generating the collective mental models around the skills shortage issue
51 are outlined below.
52

53 **5.1 Mapping previously identified issues**

54 The fifteen futures reports, selected on the basis of their potential importance to the sector,
55 were examined by content analysis to extract future issues, influencing factors and possible
56 outcomes. Categories were allowed to emerge [45], which were subsequently grouped into
57 themes. Overall, the analysis captured 386 future issues covering high-level themes of
58 technology, environment, human, economic, governance and construction-specific [20], 80 of
59 which were relevant to the skills policy agenda (see Table 1, column 3). These were used as
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1 a starting point to explore their interconnections through the development of future scenarios
 2 with professionals working in the sector. They were included based on the implications that
 3 the issues might have on the future provision of skills as suggested in the narrative of the
 4 reports, and on the judgement and experience of the research team.

5 Insert Table 1

6 **5.2. Causal map and scenario development**

7 To facilitate a meaningful debate in relation to the future and the potential interventions for
 8 achieving a preferred skills equilibrium, a way of representing the future is required. This must
 9 make explicit the subjective models of the participants in order that a collective understanding
 10 of different envisioned futures and their antecedents can be discerned. Cognitive maps have
 11 been advocated by many scholars to objectify these models, which help in the understanding
 12 and analysis of specific elements of an individual's thoughts [46,47]. In this application, the
 13 use of cognitive mapping was deemed to facilitate information structuring, elaboration,
 14 sequencing and interaction amongst participants [48]. We adopted the term 'causal map' to
 15 infer people's perception of a causal network of relationships in a form of nodes and paths
 16 [49]. Nodes contain future outcomes, issues and influencing factors, and the paths
 17 (interconnections) describe their causal relationships.

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 20 The maps were constructed on A1 paper in facilitated brainstorming workshops. Groups of 2-
 21 4 professionals identified desired outcome(s) or goal(s) within the theme under discussion on
 22 the right-hand side of the A1 paper (i.e. in the future). A total of 14 professionals participated
 23 in the process, yielding 6 scenarios (see Table 2 for scenario titles, participant job titles, and
 24 disciplines/ type of firms); the group that developed scenario 6 consisted of one professional,
 25 whose opinions were interrogated by two members of the research team. They then identified
 26 issues which are relevant predecessors to the present situation on the left-hand side (i.e.
 27 today). The space between the envisioned outcome(s) and the current situation provided
 28 room for the group to identify and debate issues, such as events, trends and strategies (both
 29 internal and external to the organisation) that might take place within the agreed timescale
 30 (usually 10-20 years). Relevant issues identified from previous reports (see above) were
 31 'offered' by the facilitator after their initial brainstorming [11]. These items can serve to re-
 32 orientate participant thinking towards meaning, scope and boundary of the theme. This is
 33 because the tendency of pluralistic interpretation of meaning and scope of a particular word or
 34 theme considered. Two people having exactly the same interpretation and understanding of a
 35 particular word is almost impossible, but their understanding could be overlapped [50,51].
 36 Finding this overlapping 'area' often provides the starting point for group negotiation, aimed at
 37 greater understanding of each other sphere of thinking. This process helps the socialisation of
 38 participant knowledge domain and facilitates common interpretation of collective futures [52].

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 40
 41 Insert Table 2

42 The final part of the 2-3 hour workshop involved each group identifying one pathway through
 43 their map as a scenario which was then recounted (and recorded) to the other groups. The
 44 causal map was digitised using Decision Explorer™ (DE) software (see example in Figure 1),
 45 allowing further analysis, identifying the most influential factors, clustering and merging the
 46 maps. The recorded narrative was also transcribed verbatim. The six scenarios presented in
 47 this paper (see Table 1, heading row) originated from three workshops and represent the
 48 opinions of senior industry representatives. The issues identified in the 6 skills maps were
 49 compared with each other and those identified from the literature (Table 1, columns 4-9).
 50 Common terms, resulting from this comparison (Table 1, column 10), were used to develop
 51 'collective' map.

52
 53
 54 Insert Figure 1

55 The outcomes of the causal mapping can be discussed in terms of structure and content.
 56 Within construction, Langford and Male asserted, echoing Gramsci [53,54], that people tend
 57 to be optimistic in the long-term but gloomy in the short-term because they can see the
 58 problems ahead. In a similar way the causal maps here typically begin with the need to
 59 improve on the existing situation or state. For example, the belief that the construction
 60

1 industry has a poor image, of being dirty, involving hard physical work and being poorly paid.
 2 Moving from the existing/current state to the envisaged future will require actions and/or
 3 events to take place. The former are mainly strategies (at a company or industry/government
 4 level) which reflects a commonly held belief of a substantial gap between the current situation
 5 and the preferred future state which is largely outside an organisation's control, i.e. a need for
 6 revised policy.

7 The content of the maps make explicit various strategies or policies:

8 Scenario 1 ("Matching supply and demand for construction labour") outlines strategies to
 9 alleviate the lack of skilled trades people in construction via recruitment and retention,
 10 and by finding other ways to deal with the problem. Important features are improvements
 11 in employment practices, e.g. by providing better conditions, and finding the right
 12 balance between recruitment, retention, using short-term migrant labour and adopting
 13 appropriate coping strategies, so that there are enough workers, without producing an
 14 oversupply in the future.

15 Scenario 2 ("Training and competence in construction health and safety") sees reduced
 16 accidents and ill-health in construction by imparting the appropriate knowledge through
 17 training, client participation, and joined-up regulations and standards. The importance of
 18 client leadership and all parties working together to achieve a common goal is
 19 particularly emphasised.

20 Scenario 3 ("Improving site conditions using offsite") suggests that increased offsite
 21 construction is not only a technological solution, but also relies on changing perceptions,
 22 client and government support, and the availability of appropriate skills. There are many
 23 concomitant sector-wide benefits.

24 Scenario 4 ("Greater emphasis on multi-skilled/ inter-disciplinary workforce") maps out
 25 potential pathways realised through a broader knowledge and range of skills. A multi-
 26 skilled workforce will provide a solution to the future skills crisis, equipping a new
 27 generation of workforce.

28 Scenario 5 ("Shortage of professional skills") focuses on possible ways to replace the
 29 projected mass retirement of engineering professionals, envisaging an international
 30 nuance to the UK labour market and continuing influence of professional institutions.

31 Scenario 6 ("Ethnic minority and female representation") proposes ways to achieve a
 32 more balanced workforce in relation to their representativeness of the wider working
 33 population, which requires government intervention and fresh approaches to raising
 34 awareness and education.

35 In summary, these six scenarios cover a range of workforce concerns, now and in the future.
 36 There are four key features in the development of strategies and actions within the scenarios,
 37 namely i) managing image and expectation; ii) leadership and intervention from government
 38 and clients; iii) joined-up thinking and actions from all stakeholders; and iv) a sustainable
 39 approach in the recruitment strategy (e.g. the balance of new entrants and foreign workers,
 40 the quality and quantity of fresh school entrants and number of graduates produced).

41 5.3. Constructing a collective multi-stakeholder map

42 The six causal maps encompass numerous issues and their interconnections; some issues
 43 are common to several maps, others are unique. Understanding the interdependencies is
 44 fundamental to ensuring their utility as a policy planning tool. A collective map attempts to
 45 represent this network of interconnections in a combined map by merging common issues or
 46 nodes, in order to facilitate an appreciation of the scope and breadth of the subject and to
 47 extend the chains of causality [55].

48 Due to the large number of issues identified from the literature and workshops, a 'screening'
 49 process was undertaken to assess each individual item for inclusion or merging in this
 50 collective map, based upon the knowledge of the research team. This produced a collective
 51 map at a relatively high (i.e. conceptual) level, avoiding unwieldy complexity. Care was taken
 52 to capture the authenticity and idiosyncrasy of the individual maps. For example, in the first
 53 few rows of Table 1 'ICT use', '3D technology (VR, CAD)', 'knowledge management', 'network
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and internet use' were merged into a single common term, 'ICT and Internet'. Some were found to straddle two (or more) common terms e.g. 'Technology and training to reduce accidents' could be classed as related to technology or 'training'. The 28 common terms in Table 1 (column 10) are located inside the box in Figure 2.

The workshops and interviews produced many issues which were not identified within the futures reports literature, adding nuanced insights of the professionals involved, and at the same time revealing the risk of over-reliance on these 'expert' sources. The same process of assessing and merging common issues within the causal maps (excluding those identified in Table 1) was undertaken, as presented in Table 3. These issues are located outside the box in Figure 2. The interconnections between issues were based upon evidence in the individual maps, with an arrow indicating a cause and effect relationship, whereas, those without suggesting a close interdependency. An example of these relationships is shown at the lower part of Figure 2. 'Flexible working' and 'work-life balance' have a cause and effect relationships, where 'flexible working' would help to achieve 'work-life balance'. However, 'flexible working' is closely associated with 'home-based working for office roles'. Taken as a whole, the collective map is considered as a merged subjective model which depicts synthesised issues related to skills and their interconnections, which will allow interrogations and evaluations of each individual issue within their wider context, i.e. in terms of their direct and indirect interconnections with other closely related issues. This map will help facilitate a discussion or debate around a particular theme by taking into consideration other issues within its problem boundary.

Insert Figure 2 and Table 3

6. Analysing the collective map

Examination of the collective map reveals that some of the issues have more interconnections than others. The number of interconnections provides an indication of the relative importance of that issue, which potentially may influence and/or be influenced by the others. The assumption is that participants tend to talk more about what they think are the important issues [50]. Identification of the issues with the higher number of interconnections was conducted using domain and central analyses within the Decision Explorer software [56].

Domain analysis simply aggregates the total number of interconnections in and out from each node (i.e. issue) and this is represented as a number, or score. It establishes linkages with other nodes within its immediate domain and provides an indication of the relative importance and influence of each individual node. However, this analysis only calculates local complexity and interconnectedness, but completely ignores the wider context of each node [57]. Central analysis extends this principle of domain analysis to include successive nodes after the immediate vicinity [58]. Central analysis traces all the nodes which are connected to the central node both directly and indirectly. Central analysis is also represented as a number, or score, which is derived by adding the original domain score to a diminishing fraction of the total number of interconnections for each successive layer, with the fraction decreasing the further the interconnections are away from the central node. For example, each node directly connected to the central node is given a weight of 1; nodes in the second layer are given a weight (or fraction) of $\frac{1}{2}$; nodes in the third layer $\frac{1}{3}$, and so on [57]. The scores for the domain and central analyses are presented in Table 4. The issues (or nodes) are listed in descending order of importance, based upon their scores. Issues with up to 4 immediate connections (i.e. with a score of 4 or higher) are included in the domain analysis column, whereas the top ten highest scoring issues are listed in the central analysis column. There is significant duplication of issues between the domain and central analyses, with eight from the central analysis being in the top eight of the domain analysis, apart from '(imbalance of) female and ethnic representation in the industry' and 'shortage of graduate entrant, apprentice and NVQs'. Further detailed analysis has been based upon these eight issues, which are likely to be those with the greatest leverage over the issues emerging in the collective map.

Insert Table 4

1 Issues within the vicinity of the eight central issues were explored and mapped using the
 2 'map' function within Decision Explorer, which maps nodes up to two levels beyond the
 3 central node. The maps produced can be considered as clusters centred around the central
 4 issue. Further examination of these maps revealed the overlaps between the issues covered
 5 by the different clusters. This overlapping can be seen in Table 5, which identifies those
 6 issues included within individual clusters. This suggests that several clusters can be
 7 represented by a smaller number of clusters. The bottom row in Table 5 presents the
 8 proportion of issues covered in cluster 8, 'use of off-site (and standardisation)'. The reason for
 9 using this cluster as the basis for comparison is because this cluster produced the highest
 10 central analysis score of all the clusters. Cluster 8 includes most of the issues within the other
 11 clusters, apart from an 'aspirational target of female/male 50/50 and ethnic balance (2026)'
 12 (i.e. cluster 4), hence, the decision to use these two clusters to represent the others.

13 Insert Table 5

14 **7. Discussion: unravelling interconnected issues**

15 Figures 3 and 4 depict the clusters 'use of off-site (and standardisation)' and 'aspirational
 16 target of female/male 50/50 and ethnic balance (2026)' respectively. The discussion regarding
 17 the research findings is orientated towards these clusters as they have the greatest centrality
 18 as explained above. These clusters help enhance the contextual understanding of the issues
 19 relating to construction skills, in terms of their causal relationships, based on the current belief
 20 of practicing construction professionals. These maps will enable policy makers to trace the
 21 line of arguments and implications of certain courses of action on the other related issues.
 22 This will help to improve their appreciation of how addressing a particular issue or problem
 23 may impact on another, hence enabling decisions to be made with a clearer idea of the
 24 potential implications. A discussion of these issues within their context follows below.

25 Insert Figures 3 and 4

26 In the first cluster, four other central issues, namely 'enough, healthy, qualified, productive
 27 labour', 'public perception', 'skill shortage', and 'training', link directly to 'use of off-site (and
 28 standardisation)'. It is not surprising that these issues have a high central analysis score as
 29 adjacent issues with higher domain scores will boost each other central scores [57]. This
 30 means that they are situated within a cluster of the most important issues within the map.

31 Although 'use of offsite (and standardisation)' is the most central issue, it could also be
 32 considered as a means to help solve the construction skills problem. To explore the chain of
 33 connections within this cluster, the others should be considered such as 'enough, healthy,
 34 qualified, productive labour' as a potential goal. To realise this goal, the construction sector
 35 would need to increase the 'welfare and improvement of labour force', increase 'use of offsite
 36 (and standardisation)', enhance 'training', manage the 'immigration and emigration' of
 37 workforce, and balance or increase 'female and ethnic representation in the industry'. All of
 38 these issues are connected to 'use of offsite (and standardisation)' within the map. Increasing
 39 the 'use of offsite (and standardisation)' to help alleviate the problems due to the 'skill
 40 shortage' and the associated 'ageing population', would also need an improved 'public
 41 perception' towards working in construction and a more pro-active involvement from the
 42 government and clients. 'Public perception' of the construction sector would be improved if
 43 both the poor general welfare of the workforce and the image of the industry in the media
 44 were addressed. It is interesting to note the significant role of government and clients in the
 45 debate, as perceived by construction practitioners. Skills Observatories, which are
 46 established at a regional level, are envisaged as helping to improve the public, government
 47 and client's perceptions of the sector as a whole, and endeavour to raise awareness in order
 48 to help alleviate the skills problem. However, their longer-term effectiveness is yet to be
 49 established since they are a fairly recent initiative [23].

50 In the second cluster (Figure 4), if the 'aspirational target of female/male 50/50 and ethnic
 51 balance (2026)' is taken as a goal, then the arrangement of the 'explanatory' issues would
 52 resemble a hierarchical pyramid [57]. That means that the issues at the lower levels of the
 53 hierarchy explain those at the higher levels. Increased participation by female and ethnic
 54 minorities has been suggested as a strategy to cope with the skills problem [59]. The

1 perceived poor image of the industry and propensity for discrimination and harassment in the
2 workplace are common reasons for poor participation [60]. Although equality legislation and
3 initiatives have taken into effect in recent years, women remain seriously under-represented
4 in the UK construction sector due to impeding structural and cultural factors and working
5 practices (see for example [44,61]). Furthermore, Dainty and Lingard [62] argue the need for
6 cultural and attitudinal shifts, endowed with strong social support in the working place in order
7 to encourage non-traditional recruits. Although this is not an easy task, the growing pressure
8 to tap the potential of all layers of society and to realise diversity in the workplace would mean
9 more active recruitment of this working population in the future.

10 As indicated by the issues supporting (i.e. with arrows going into) the 'aspirational target of
11 female/male 50/50 and ethnic balance (2026)', actions which could be adopted to promote
12 participation, include positive discrimination for females and those from ethnic minority
13 backgrounds, embracing a work-life balance, technology transfer activities (i.e. bringing ideas
14 from another industries), equipping teachers with more commercial experience, shaping
15 public procurement to help drive equality, initiating business diversification and opportunities,
16 enhancing the working environment (by e.g. adopting appropriate technology) and improved
17 public perception in general. These actions would, in turn require supporting actions. A better
18 public perception of construction could be achieved through improved welfare of the labour
19 force and established role models in the popular media, policies to accommodate workforce
20 flexibility by allowing part-time work and a combination of office and home-based working.
21 Prioritising female and ethnic minority applications for university scholarships would also
22 encourage them to join construction, although the wider implications of this on equal
23 opportunity legislation remains to be justified. There is a strong government influence in the
24 implementation and potential success of the preceding endeavours. Government action
25 through e.g. establishing legislation, would encourage better public procurement, business
26 diversification and opportunities, and technology transfer, which should all be conducive to
27 encouraging female and ethnic minority recruitment. Surprisingly, there has been little
28 consideration of policy measures which could arguably influence many of the issues
29 contained within the collective map. This may be because the nature of the participants
30 inherently determines the issues in the causal map. The clear causality of these potential
31 interventions and outcomes emphasises the tightly interwoven and interconnectedness of the
32 skills agenda with the wider image and societal position of the construction sector.

33 **8. Conclusions**

34 Recent years have witnessed the revival of the use of scenario planning, and a consequent
35 increase in the volume of published literature in the area [63]. A review of existing literature
36 suggests that much has been written about the process of developing scenarios and the
37 benefits of the process, but less on the content and nature of the scenarios themselves. In
38 addition, there is also a dearth of literature reporting on the analysis of scenarios developed in
39 a multi-organisational context in order to address an issue of mutual importance. More
40 specifically, the analysis of a large number of issues and their interconnections, which
41 scenario development involving a variety of stakeholders is likely to yield, has not been made
42 explicit for studying and enhancing understanding a complex societal problem, such as
43 construction skills shortage.

44 The difficulties surrounding the construction skills problem are viewed by many as a
45 manifestation of the complex interplay amongst different issues. Despite numerous attempts
46 to address the skills problem in construction, there has been little endeavour in trying to
47 unravel the complexity of the problem in a holistic manner with the involvement of key
48 stakeholders. This paper has reported the development of a method for building and
49 analysing scenarios as manifested in a complex network of the interconnected issues around
50 the issue of construction skills shortages. The analysis of such a complex network represents
51 a significant challenge for researchers in this field [64]. The method was employed in a series
52 of participative scenario development workshops, yielding a series of related causal maps.

53 A collective map merging the individual subject-specific causal maps was created to help
54 provide a more holistic overview of the pertinent issues surrounding the construction skills
55 debate. This collective map extends both the scope and the chain(s) of causality of the
56 subject as a means of assessing the possible knock-on effects and implications of potential
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1 intervention strategies. The analysis helps yield a better understanding of the issue in a wider
 2 context, including the potential consequence of possible future events and actions, and of the
 3 pre-requisite required for certain events/desired outcomes to take place. Although delegates
 4 recognised the benefits of the exercises in terms of stimulating further debate, the workshops
 5 took a longer time and were deemed intellectually more demanding compared to more
 6 common scenario-building workshops.

7 A key benefit that could be derived from this method is the opportunity to help facilitate and
 8 encourage debate and discussion amongst key stakeholders regarding the skills improvement
 9 agenda within the construction sector. One such discussion has been demonstrated here
 10 using two main subject clusters derived from the wider collective map. The outcome has
 11 promoted a greater understanding of the issues surrounding the skills problem, and is
 12 potentially useful in the development of informed skills planning policies. The method helps to
 13 'make more sense' of the causal relationships between issues in the collective map by
 14 reducing the number of issues to a limited number of key influential issues. Due to the built-in
 15 flexibility and adaptability of the collective map and associated software, the same approach
 16 could also be adopted and tailored to suit the needs of a particular organisation or individual
 17 wanting to investigate a specific issue relating to skills in construction. Perhaps of more
 18 significance is the potential to apply this method to other areas requiring longer range
 19 planning and which contain multiple stakeholder perspectives. This concurs with the findings
 20 by Varum and Melo [63], who argue that scenario planning methods are commonly adaptable
 21 to different contexts given their flexibility. By allowing for the combination of related causal
 22 maps and mapping their interconnectivities, the technique allows for the systematic
 23 integration of multiple perspectives when considering longer term policy decisions. It therefore
 24 offers a new approach for accounting for multiple and parallel drivers of change across a
 25 range of contexts.

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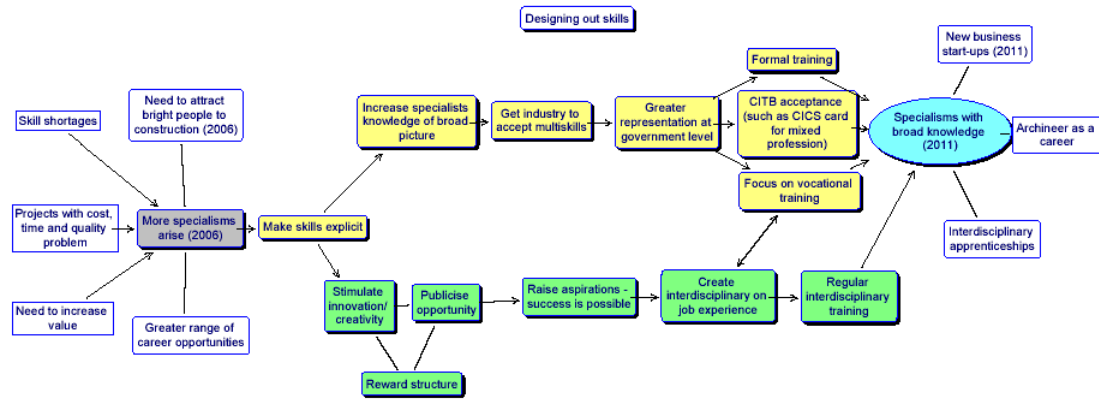


Figure 1 An example of causal map (Scenario 4: “Greater emphasis on multi-skilled/ interdisciplinary workforce”)

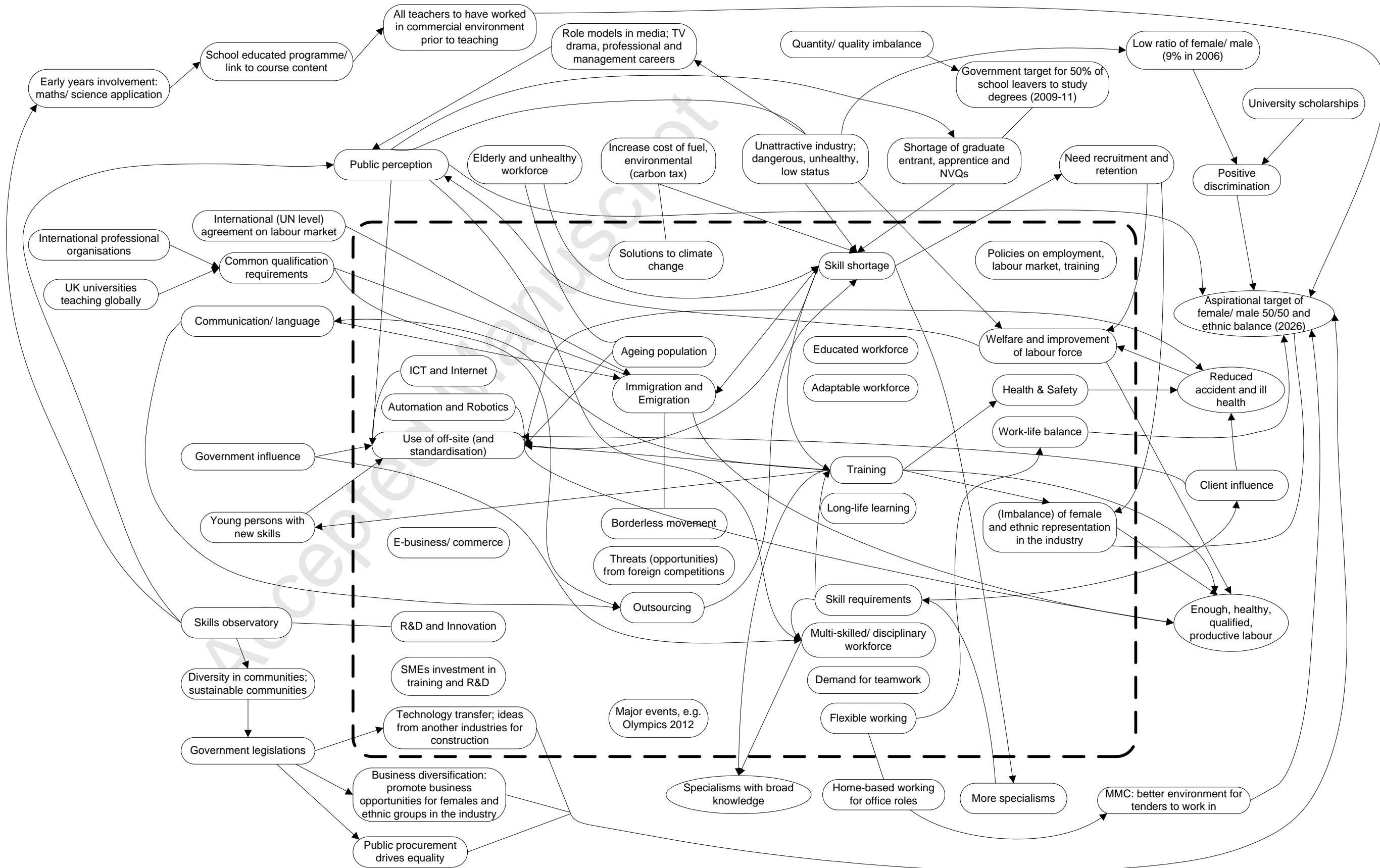


Figure 2 A collective map of construction skills

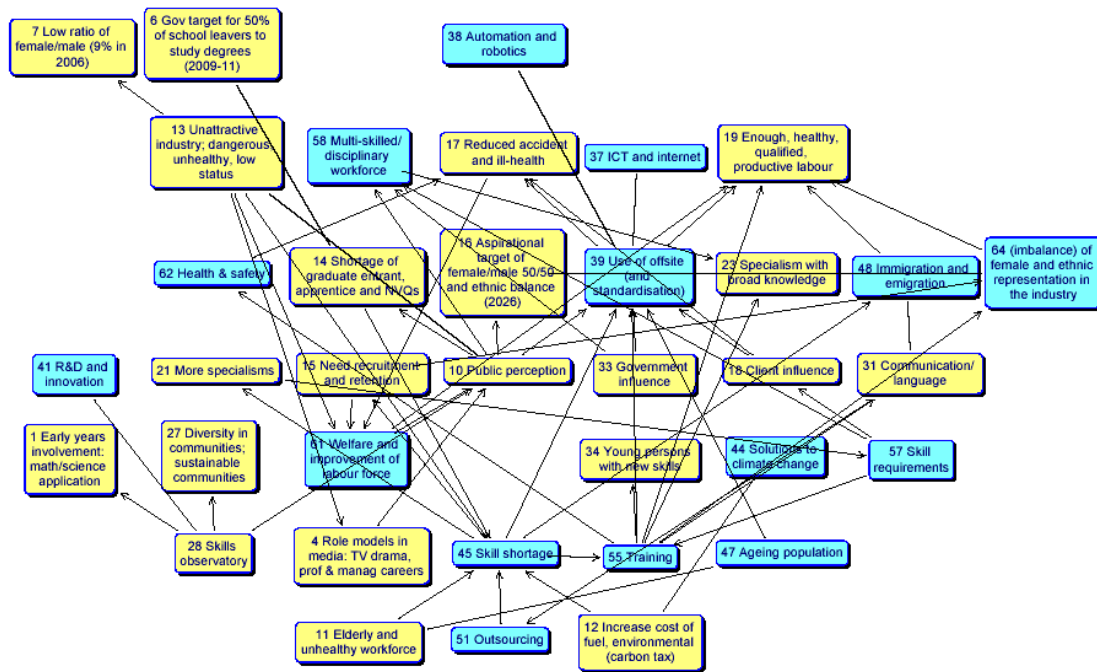


Figure 3 Issues and factors clustered around 'use of off-site (and standardisation)'

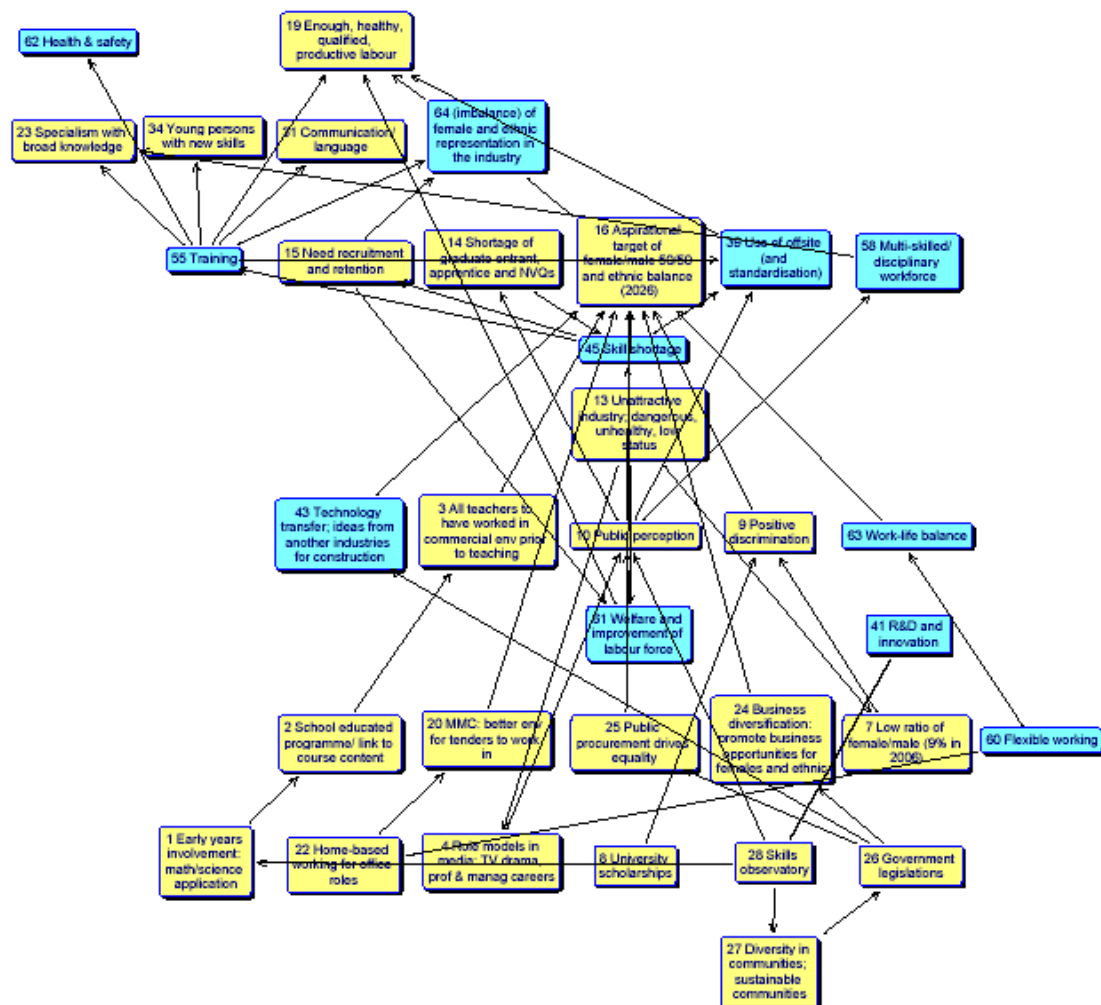


Figure 4 Issues and factors clustered around 'aspirational target of female/male 50/50 and ethnic balance (2026)'

Table 1 Identification of issues from literature and causal maps									
Construction Futures Reports			Causal Maps from Workshops						Common Term
Category	Issues	Related to Skills	Scenario 1: Matching supply and demand	Scenario 2: Training and competence	Scenario 3: Site Conditions	Scenario 4: Multi-skilled/ interdisciplinary workforce	Scenario 5: Shortage of professional skills	Scenario 6: Ethnic minority and female representation	
Technological	ICT	ICT use	*						ICT and Internet
		3D technology (VR, CAD)	*						
		Knowledge management	*						
		Network and internet use	*						
		Sensor technology			*				Automation and Robotics
	Automation	Robots use	*						
		Sensors and control equipment in building			*				
Off-site & standardisation	Off-site & standardisation	*	*		*				Off-site & standardisation
	New manufacturing technologies	*							
Environmental	Sustainability	Innovative approaches to sustainability	*						
		Reduce waste		*					
		CO2 production/ emission		*					
		South East (London) as competitive global hub	*						
	Demography	Demography profile	*						
		Ageing population (UK)	*		*				Ageing population
		Young people in workplace (availability of workforce)	*				*		
		Increasing migration (and emigration)*	*			*		*	Immigration and Emigration
	Radical solutions to climate change*	*						Solutions to climate change	
	Oil depletion		*						
General	Local resources		*						
Human	Education	Educated workforce	*				*		Educated workforce
		Long-life learning	*						Long-life learning
		Generalist education	*						
		Knowledge redundancy	*						
		Knowledge is more important than judgements	*						
		Failing of engineering and construction education	*						
	Skills & training	Training	*	*	*	*	*		Training
		Skill levels	*						
		Skill and capability requirements	*		*	*	*	*	Skill requirements
		Flexibility, creativity, less hierarchical, intelligence skills	*						
		Appropriate balance of skills (hard and soft)	*						
		Skills: deal-making, service innovation, relationship man	*						
		Multi-skilled/disciplinary workforce	*				*		Multi-skilled/ disciplinary workforce
		Increase ability of multi-language among professionals#	*						
		Skills in cultural expression and translation	*						
		Urban analysis and design skills	*						
		Self-employed	*						
		Contract-based	*						
		Professional barriers/ boundaries	*				*		
		Knowledge management and information sharing	*						
		Knowledge and technology-based skills	*		*				
		New skills (IT and supply chain)	*						
		Skills to model and pre-test design solutions	*						
	ICT de-skilling the work of the professions	*							
	Technology and training to reduce accidents	*		*					
	Shortage of (engineering) professions	*				*	*		
	Shortage of skilled workers	*	*			*		Skill shortage	

Construction Futures Reports			Causal Maps from Workshops						Common Term	
Category	Issues	Related to Skills	Scenario 1: Matching supply and demand	Scenario 2: Training and competence	Scenario 3: Site Conditions	Scenario 4: Multi-skilled/interdisciplinary workforce	Scenario 5: Shortage of professional skills	Scenario 6: Ethnic minority and female representation		
Human	Employment	Mechanisation of manual jobs	*	*						
		Shift in employment from manufacturing to services	*							
		Mobility of workforce	*							
		Adaptable workforce	*						Adaptable workforce	
		Flexible working	*						Flexible workforce	
		Teleworking	*						*	
		Emergence of knowledge workers	*							
		Welfare and improvement of labour force	*	*				*		
		More emphasis on job satisfaction and care of workforce	*	*	*					
		Health and safety	*	*	*					
		Reasonable job security	*	*						
	People and Society	Integrated lifestyle (work, family & leisure) 'work-life balance'							*	Work-life balance
			Personal productivity (as influenced by ICT, internet, TV) #	*						
			Demand for teamwork (real and virtual)	*						Demand for teamwork
		Digital natives' - growing up accustomed to technology"	*							
		Nervousness of older people towards technology	*							
	London Olympic 2012	*							Major events, e.g. Olympics 2012	
Economic	Business	Knowledge-based economy	*							
		Borderless movement	*	*		*		*		
		Threat from foreign competition	*							
		Empowering customer	*			*				
		China and India being the world's largest markets/ Asian ec growth	*							
		Commercial opportunities in developing countries	*							
		Greater outsourcing	*					*		
		Growth in services, decline in manufacturing & agriculture	*							
		Emergence of few large firms and brands	*							
		Increased specialisation for small firms	*							
		Continual innovation for survival	*				*			
		Capacity of firm to innovate	*							
	Regional/ local business initiatives	*				*				
	E-business/ commerce	*							E-business/ commerce	
Governance		Governance and regulation							*	
		International government'					*			
		Environmental taxes		*						
		Policies to respond climate change		*						
		Policies on employment, labour market, training	*						*	
		Public opinion	*		*	*	*	*	*	
		Building regulations	*		*					
	Policies providing construction skills training	*				*				
Construction industry-specific	Structure and Process	Automatic procurement system	*							
		Less adversarial procurement, i.e. partnering	*							
		ICT-enabled collaboration and co-operation	*							
		Need for risk management			*					
		Imbalance of ethnic and female representation in the industry	*	*				*	*	
		Site working conditions (H & S)	*	*	*					
	Design	Value added design processes			*					
	R & D and innovation	R & D and technology transfer	*						*	Technology transfer; ideas from another industries for
		R & D and innovation					*			R&D and innovation
		Research competencies and facilities	*							
		Ideas of technology use in other industries	*			*			*	
	SMEs' investment in training and R & D	*							SMEs investment in training and R&D	

Table 2 Scenarios and participants of the workshops

No.	Scenario title	Participant job title	Discipline
1	Matching supply and demand for construction labour	Principal inspector	Health & safety in construction
		Construction inspector	Health & safety in construction
		Principal specialist inspector	Health & safety in construction
2	Training and competence in construction H&S	Construction Division Technology Unit	Health & safety in construction
		OPS Glasgow	Health & safety in construction
3	Improving site condition using offsite	Principal specialist inspector	Health & safety in construction
		Principle construction inspector	Health & safety in construction
		Construction inspector	Health & safety in construction
4	Greater emphasis on multi-skilled/ inter-disciplinary workforce	Director	Engineering consultant
		Chief executive	Contractor
5	Ethnic minority and female representation	Regional manager	Construction quango
		Regional manager	Construction quango
		Manager	Construction quango
6	Shortage of professional skills	Regional manager	Civil engineering

Table 3 Issues identified from individual causal maps						
Issues	Causal Maps					
	Scenario 1: Matching supply and demand	Scenario 2: Training and competence	Scenario 3: Site Conditions	Scenario 4: Multi- skilled/ interdisciplinary workforce	Scenario 5: Shortage of professional skills	Scenario 6: Ethnic minority and female representation
Early years involvement: maths/science application						*
School educated programme/link to course content						*
All teachers to have worked in commercial environment prior to teaching						*
Role models in media; TV drama, professional and management careers						*
Quantity/quality imbalance					*	
Government target for 50% of school leavers to study degrees (2009-11)					*	
Low ratio of female/male (9% in 2006)					*	
University scholarships						*
Positive discrimination					*	*
Public perception			*	*	*	*
Elderly and unhealthy workforce	*		*			
Increase cost of fuel, environmental (carbon tax)	*					
Unattractive industry; dangerous, unhealthy, low status	*		*		*	
Shortage of graduate entrant, apprentice and NVQs	*					
Need recruitment and retention	*			*	*	*
Aspirational target of female/male 50/50 and ethnic balance (2026)					*	*
Reduce accident and ill-health		*	*			
Client influence		*	*			
Enough, healthy, qualified, productive labour	*					
MMC: better environment for tenders to work in			*			*
More specialisms				*		
Home-based working for office roles						
Specialisms with broad knowledge				*		
Business diversification: promote bus opp for female and ethnic groups						*
Public procurement drives equality						*
Government legislations		*	*			*
Diversity in communities; sustainable communities						*
Skills observatory						*
Young persons with new skills			*			
Government influence		*	*	*		*
Communication/language		*			*	
Common qualification requirements					*	
International (UN level) agreement on labour market					*	
International professional organisations					*	
UK universities teaching globally					*	

Table 4 Aggregate scores for the domain and central analyses

Domain Analysis		Central Analysis	
Issue	Score	Issue	Score
Skill shortage	10	Use of offsite (and standardisation)	24
Training	9	Public perception	24
Aspirational target of female/male 50/50 and ethnic balance (2026)	8	Training	23
Use of offsite (and standardisation)	8	Skill shortage	23
Public perception	7	Aspirational target of female/male 50/50 and ethnic balance (2026)	22
Enough, healthy, qualified, productive labour	5	(Imbalance of) female and ethnic representation in the industry	20
Welfare and improvement of labour force	5	Enough, healthy, qualified, productive labour	20
Unattractive industry; dangerous, unhealthy, low status	4	Unattractive industry; dangerous, unhealthy, low status	20
Reduced accident and ill-health	4	Welfare and improvement of labour force	19
Government legislations	4	Shortage of graduate entrant, apprentice and NVQs	19
Common qualification requirements	4		
Immigration and emigration	4		
Skill requirements	4		
Multi-skilled/disciplinary workforce	4		

Clst No.	Issue Description	Cluster							
		1	2	3	4	5	6	7	8
	Early years involvement: maths/ science application								
	School educated programme/ link to course content								
	All teachers to have worked in com env prior to teaching								
	Role models in media; TV drama, prof and man careers								
	Quantity/ quality imbalance								
	Gov tgt for 50% of sch leavers to study degrees (2009-11)								
	Low ratio of female/ male (9% in 2006)								
	University scholarships								
	Positive discrimination								
7	Public perception							X	
	Elderly and unhealthy workforce								
	Increase cost of fuel, environmental (carbon tax)								
2	Unattractive industry; dangerous, unhealthy, low status		X						
	Shortage of graduate entrant, apprentice and NVQs								
	Need recruitment and retention								
4	Aspirational tgt of female/male 50/50 and ethnic bal (2026)				X				
	Reduced accident and ill health								
	Client influence								
3	Enough, healthy, qualified, productive labour			X					
	MMC: better environment for tenders to work in								
	More specialisms								
	Home-based working for office roles								
	Specialisms with broad knowledge								
	Business diversification: prom bus opp for fem and ethnic gr								
	Public procurement drives equality								
	Government legislations								
	Diversity in communities; sustainable communities								
	Skills observatory								
	International (UN level) agreement on labour market								
	Common qualification requirements								
	Communication/ language								
	Government influence								
	Young persons with new skills								
	International professional organisations								
	UK universities teaching globally								
	ICT and Internet								
	Automation and Robotics								
8	Use of off-site (and standardisation)								X
	E-business/ commerce								
	R&D and Innovation								
	SMEs investment in training and R&D								
	Technology transfer; ideas from another industries for const								
	Solutions to climate change								
5	Skill shortage					X			
	Policies on employment, labour market, training								
	Ageing population								
	Immigration and Emigration								
	Borderless movement								
	Threats (opportunities) from foreign competitions								
	Outsourcing								
	Major events, e.g. Olympics 2012								
	Educated workforce								
	Adaptable workforce								
6	Training						X		
	Long-life learning								
	Skill requirements								
	Multi-skilled/ disciplinary workforce								
	Demand for teamwork								
	Flexible working								
1	Welfare and improvement of labour force	X							
	Health & Safety								
	Work-life balance								
	(Imbalance) of female and ethnic rep'tation in the industry								
	Proportion of issues covered in cluster 8 (%)	100	95	94	65	94	100	100	
Note:									
X	: indicates central issue								
	: indicates issues within immediate vicinity of central issue								
	: indicates related issues								