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REAL-TIME ASSESSMENT OF REGULATORY COMPLIANCE OF CONSTRUCTION SITES

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Abstract

Previous work on automatic compliance checking has targeted static descriptions of the built environment represented in Building Information Models. In contrast, this work examines the potential of semantic mark-up to capture and then apply health and safety regulations to live construction sites. There are significant differences in what constitutes a testable metric and what constitutes a fact when considering process rather than product compliance. Extensions to the RASE approach are defined and demonstrated to accommodate these differences. This leads to extending the concept of 'decidability' with considerations around the relative 'timeliness' of information.

Introduction

Previous work has applied the RASE method to building regulations and other static assessments of building proposals. The paper examines how automated compliance checking of construction site processes differ from the compliance checking of facility models. The attention on wellbeing, health and safety in construction (WHS) is widening from retrospective consideration of reconstructions of past accidents and near-misses scrutinized in enquiries and hearings (Pirzadeh et al., 2017). Besides safety, compliance requirements provide rules that may be best assessed live, rather than retrospectively. Thus, WHS presents a suitable case to develop theory and practice on automated compliance checking for processes in construction work.

There has been an increasing use of contemporaneous and real-time monitoring of construction activity on site (Cheng et al., 2013). This can support the immediate triggering of alarms and warnings about safety due to the proximity of incompatible entities, such as heavy plant and operatives. One source of the rules for such triggering is the legislation and regulations defining safety compliance. These rules can be checked against real-time construction activity data and static information about construction sites, such as project planning and resourcing (PERT) plans, 3D and 4D models and methods of work statements. This paper examines examples of real-time information sources and safety regulations to propose how semantic mark-up based on the RASE methodology (Nisbet et al. 2008) can be adapted to provide machine-operable rules that can be evaluated continuously for automated compliance checking for construction processes. RASE is a mark-up approach that highlights the logical structure and metrics in documents, as illustrated below.

Previous work

There has been previous work on rules about construction sites, dynamic assessment in other sectors, rule capture and the representation of time in predicate logic.

Many recent works have focused on 'prevention through design' looking for design features in static BIM models which may indicate specific hazards that may need consideration during construction planning (Johansen et al., 2023; Schwabe et al., 2019; Tekbas et al.,2020; Yuan et al., 2019). Shen et al. (2022) used the term 'dynamic' to refer to the importance of the sequence of processes anticipated when following work procedures. The target of the rule checking was a '4D' BIM description and narrative. Rules were obtained by transcribing knowledge onto a product/activity/location template along with the hazard and solutions. Queries were accepted in free text with NLP being used to map terms to the template. Bao et al. (2022) used a static BIM model and additional safety measures inserted automatically by third-party software. Scripts detected topological adjacency information. Sequencing was obtained from the project PERT (program evaluation and review) plan. Rules were translated into SQL (structured query language) expressions. The outcomes were alerts within the BIM authoring platform with recommendations for improvements prior to construction commencing.

Continuous real-time assessment of dynamic construction sites is being considered as an aspect of digital twins (Li et al., 2021). Teizer et al. (2022) proposed a combined view seeking to ensure safety through (a) design and construction planning, (b) risk detection and (c) learning and feedback. The choice of rules to be applied was left open.

Pradhananga (2015) explored the tracking of heavy plant using GPS and the visualization of those tracks around work, hazard, material, travel, loading and dumping zones. Zones could be taken from GIS (geospatial information system) or BIM (building information modelling) information or deduced from the behaviour of vehicles. Productivity was measured by repetitive cycle times. Speed and proximity were detected as leading indicators for hazards. Xu (2023) developed a fuzzy-logic tree combining live monitoring weather, location and worker IoT feeds to generate a continuous feed assessing worker well-being and risk. Rules were acquired by agreeing decision tables and fuzzy logic tables of risk and association. Other sectors have similar needs but within a static built environment and with static operational patterns. For example, Yang et al., (2023) examined vehicle conflicts at airports. The work deduced rules from safety critical correlations between vehicle speeds, accelerations and convergence. Li et al. (2022) combined engineering and soil monitoring values to alert possible construction risks, using SPARQL (RDF query language) applied to the combined data sets. Nisbet et al (2023) has raised concerns concerning the use of SPARQL.

RASE is a mark-up approach to identify the logical structure and semantic metrics in normative text, by identifying sections and phrases as Requirements, Applicability, Selections or Exceptions. RASE has been applied to static rule situations such as comparing building proposals against planning (zoning) and building control (technical) regulations (Beach et al., 2020 and 2023). RASE has been shown to be able to generate propositional and predicate logic statements (Nisbet et al., 2022). RASE was selected for its 'no-code' approach offering transparency to both inspectors and constructors.: mark-up can be added, reviewed and, if necessary, improved, by domain experts. This 'white-box' approach is in contrast to conventional translation and programming which remains opaque to domain experts.

Whereas most discussions of propositional and predicate logic assume a static context, built around the present tense, rules about live environments may need to consider 'temporal logic' capturing the sequence of the processes of interest. This has extensive literature, given its importance in legal and contractual and computational analysis, summarized in Lamport (1994).

There are two candidate modes for temporal logic, one based on representing events, and the other based on representing intervals. Temporal logic can be expressed in predicate logic by considering the role of four verb tenses. Ploug et al. (2012) summarised previous work including Prior and Kripke who proposed four tenses P "It has at some time been the case that …" F: "It will at some time be the case that …" H: "It has always been the case that …" and G: "It will always be the case that …" which can be combined to generate more complex tenses. In order to integrate event-based view into predicate logic the operators 'before' and 'after' can be used to relate two disjointed predicate statements.

In summary, literature has focused on identifying invariant rules on facility designs and construction plans that must be true continuously but has not addressed the dynamic narrative around events on construction sites and the means to capture and apply such rules. There is a gap in the literature related this real-time assessment of construction process compliance.

Method

Given the uncertainties and lack of previous work, a design science research approach has been taken to explore and iterate towards a plausible approach. This allows the solution space to be explored without necessarily discovering all the limitations of the solution. Part of that solution space includes the use of existing ontologies around safety and built environment.

This approach was supported by a workshop invitation issued by the Health and Safety Executive (HSE), a UK regulatory body, as part of their 'Discovering Safety' programme. The HSE encouraged the engagement of three commercial solution providers each addressing live construction site information, and the lead author as an information integrator.

The following section examines some relevant theory and ontology resources. The next section then looks at the preparatory work applying RASE semantic mark-up to Clause 22 of the UK Construction (Design and Management) Regulations 2015 (C(D&M) 2015), prior to considering specific information sources. This paper then reports on experiments to examine information sources around some specific scenarios, how these map to target ontologies and how these information resources can be continuously tested. Each experiment iterated progressively towards an improved rule representation and a rule-engine to test its utility.

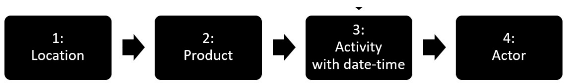
Theory

This section examines theory and ontology for safety compliance checking of construction processes including for the target model, for dictionary resources and for rules.

Ontology for construction processes including health and safety

Both IFC (ISO 16739-1, 2024) and classification standards (ISO 12006-2, 2015) use a four-layer model for the descriptive and narrative representation of the built environment. The top-most layer describes the built environment in terms of named locations and spaces. These spaces are defined and supported by physical objects. These physical objects are affected by processes, activities and events. The processes are supported by resources including actors and construction aids.

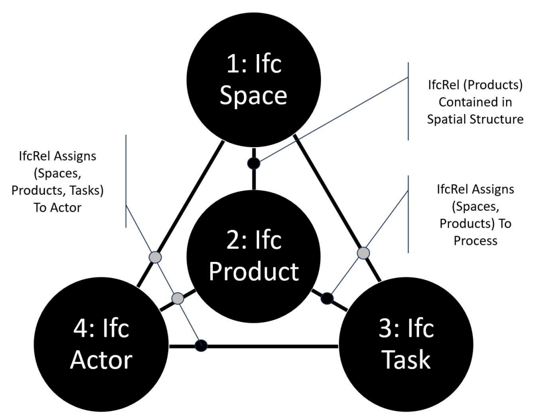
This suggests that a tabular representation (Figure 1) can be used to track all the activities and timings (3) happening on the construction site with associated locations (1), products (2) and actors (4).



1: Location		2: Product		3: Activity			4: Actor	
Name	Description	Name	Description	Name	Description	Date and Time	Name	Description
S1	Site	B1	Facility	45246	Shift	16/11/2023 08:00	-	-
EX1	Excavation	-	-	IN1	Introduction	16/11/2023 08:10	CW1	Crew
EX1	Excavation	-	-	IN2	Introduction	16/11/2023 08:15	EX1	Excavator
EX1	Excavation	-	-	VW1	Inspection	16/11/2023 08:25	SE1	Engineer
EX1	Excavation	-	-	AP1	Approval	16/11/2023 08:35	SE1	Engineer
EX1	Excavation	-	-	EV1	Landslip	16/11/2023 08:47	CW1	Crew

Figure 1: Tabular information model and sample

In situations where there are multiple information sources available, a unifying ontology may be needed. IFC offers a comprehensive descriptive and narrative schema. Typical BIM models provide the physical product and some spatial location entities. To consider the dynamics of a construction site activity, tasks, events and actors are included in addition. Figure 2 shows the four IFC entity types in a tetrahedral arrangement. All six possible inter-relationships are provided by three IFC objectified relationship entities. The ability to sequence activity is also illustrated in the sample.




```
#11 = IFCSPACE(...  , 'EX1', 'Excavation 1', $, #91, $, $, .ELEMENT., .EXTERNAL., $);
#12 = IFCMEMBER(... , 'SP2', 'Excavation support', $, #92, #93, $);
#13 = IFCTASK(...   , 'SH3', 'Shift 3', 'Work shift', 'SH3', '', 'Shift start', .F., $);
#14 = IFCACTOR(...  , 'SE4', 'Site engineer 4', 'Engineer', #94);

#21 = IFCRELCONTAINEDINSPATIALSTRUCTURE(... , (#12),    #11);
#22 = IFCRELASSIGNSTOPROCESS(...            , (#11), $, #13, $);
#23 = IFCRELASSIGNSTOPROCESS(...            , (#12), $, #13, $);
#24 = IFCRELASSIGNSTOACTOR(...              , (#11), $, #14, $);
#25 = IFCRELASSIGNSTOACTOR(...              , (#12), $, #14, $);
#26 = IFCRELASSIGNSTOACTOR(...              , (#13), $, #14, $);

#26 = IFCRELSEQUENCE(...                    , #13,      #15, 0, .FINISH_START.);
```

Figure 2: IFC ontology and sample

Some information sources may lack structuring so consideration can be given to automated or manual RASE mark-up of diary and monitoring entries (Figure 3) either to read directly, obtain tabular information or generate IFC data. Figures 3, 4, 5 and 6 show Requirements in blue with underlining, Applicability in green with dashed underlining, Selection in purple with dotted underlining and Exceptions in orange with double underlining.

Site engineer SE1 issues approval AP1 at 2023-11-16T09:05 of excavation EX1.

Figure 3: Narrative text with RASE as an information model

UK BSI PAS 1192-6 (2018) offers a model of safety risks. The comparability of risks in a shared risk register is supported by the consideration of likelihood and consequence. Likelihood is considered as the outcome of the effects of physical product (P), process activity (A) and spatial location (L). This 'PAL' model omits the consideration of the actors responsible for or engaging in activities so as to shift the emphasis away from operator error and towards systemic factors. This is intended to make safety risk information more shareable, generalisable and reviewable. Regulatory considerations often additionally address actor roles so that responsibility and accountability can be assigned when compliance is assessed. Uniclass (2023) tables can be used to classify the locations (SL), products (Pr), activities (Ac), roles (Ro) and also the resulting risk (RK).

Ontology for dictionaries

Previous work has shown that dictionaries can be used to relate concepts from different domains, including relating names, descriptions and classifications and properties, or concepts from natural language and specific data schemas (ISO 12006-3, 2022). Nisbet et al. (2024) showed how ordinary text and tables can be marked-up to serve as dictionary resources.

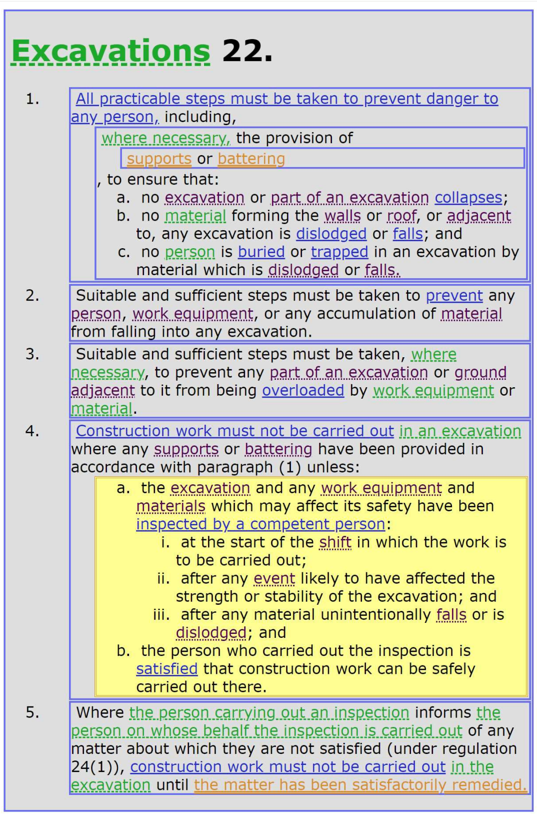
Ontology for normative knowledge

RASE captures the ontology of knowledge embodied in First Order Logic. This can be summarized as an executable tree hierarchy of logical operators applied to objectives and testable metrics. Normative knowledge as a logical statement of how the world is required to be, may be wrapped in deontic logic around duties and obligations which are usually handled externally by administrative or operational action. In the current example the action may include 'enforcement' by the HSE authorities.

Preparations

EU UK legislation and secondary legislation and regulations are publicly accessible. An example is EU Directive 92/57/EEC (EP 1992) which is implemented in the UK as the C(D&M) 2015 regulations that are applicable to most construction activity. These regulations comprise clauses 1-15 concerning the allocation of responsibilities and roles, and clauses 16-39 which define 'general requirements for all construction sites'. Clause 22 considers the steps expected for the safe execution of excavations. Sub-clause 22(1) is problematic in that it refers to 'all practicable steps' and the ill-defined qualification 'if necessary'. This sub-clause will be considered in the Discussion section. The text of clause 22 is available as HTML and has been marked up with RASE (Figure 4) using 'AEC3 Require1' (AEC3, 2024).

Sub-clause 22(4) is a particularly significant clause in that it explicitly bans construction work within excavations unless certain conditions are met. The Requirement is that no construction activity is carried out. This has Application to excavation locations but only if a Selection from supports and battering (sloping sides) is present. A substantial Exception then identifies the events which should trigger an inspection and satisfaction. Whilst most of the events are discrete and independent, the inspection and satisfaction are related and dependant to those events. This relationship is not captured by the visible mark-up. However, each RASE mark-up can contain metadata which can be made visible when a mouse hovers over the mark-up ('mouse-over event'). Previously this metadata has given each mark-up an identifier 'id' and the naming of the RASE class 'Type'. Optionally metrics can have 'Property', 'Comparator', 'Target' and 'Unit' added to deconstruct any numeric metric. Optionally sections can have a 'Outcome' to record where any intermediate outcome is of interest. In HTML each piece of metadata is stored as an attribute on the tags, prefixed with 'data-rase' which combines the convention for extensions to HTML markup with a RASE specific identifier.


Excavations 22.

1. All practicable steps must be taken to prevent danger to any person, including,
   where necessary, the provision of
   supports or battering
   , to ensure that:
   a. no excavation or part of an excavation collapses;
   b. no material forming the walls or roof, or adjacent to, any excavation is dislodged or falls; and
   c. no person is buried or trapped in an excavation by material which is dislodged or falls.
2. Suitable and sufficient steps must be taken to prevent any person, work equipment, or any accumulation of material from falling into any excavation.
3. Suitable and sufficient steps must be taken, where necessary, to prevent any part of an excavation or ground adjacent to it from being overloaded by work equipment or material.
4. Construction work must not be carried out in an excavation where any supports or battering have been provided in accordance with paragraph (1) unless:
   a. the excavation and any work equipment and materials which may affect its safety have been inspected by a competent person:
      i. at the start of the shift in which the work is to be carried out;
      ii. after any event likely to have affected the strength or stability of the excavation; and
      iii. after any material unintentionally falls or is dislodged; and
   b. the person who carried out the inspection is satisfied that construction work can be safely carried out there.
5. Where the person carrying out an inspection informs the person on whose behalf the inspection is carried out of any matter about which they are not satisfied (under regulation 24(1)), construction work must not be carried out in the excavation until the matter has been satisfactorily remedied.

Figure 4: RASE markup of Clause 22

One way of understanding this complexity of related events is to ask what it is that potentially fails. It is not the individual events, nor the excavation but the sequence of events and inspections – the timeline – that passes or fails. Some metrics depend on the state of the excavation, in terms of the presence or absence of 'work', 'supports' and so on. Based on the work on 'temporal logic' discussed in the literature review section, it is necessary to record that certain events such as 'inspections 'and 'satisfactions' are not only required but must be in a specific relationship to the events and states, specifically coming later in a timeline.

This means that the requirement for inspection is actually for a 'subsequent inspection' and the requirement for satisfaction is actually for 'subsequent satisfaction'. The 'subsequent' test is in each case relative to a previous entry in the timeline. This can be achieved by adding an additional item of metadata 'Reference' which can ensure that the test for an inspection is applied, not to the whole timeline (has there been an inspection ever?) but to the timeline since the triggering event (has there been an inspection since that triggering event?), and similarly can ensure that the test for 'satisfaction' is applied, not to the whole timeline (has there been a satisfaction event ever?) but to the timeline since the inspection event (has there been satisfaction since that inspection?).

With this addition, the marked-up regulation can be reported back, for example as a conceptual graph (Solihin et al., 2015) of distinct metrics as seen in figure 5.

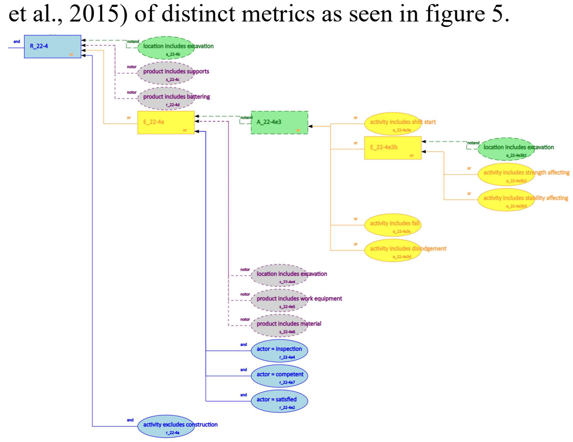


Figure 5: Reflection of Clause 22(4) as a conceptual graph

Reviewing the list of metrics, it is clear that some terms need synonyms. These can be plain language synonyms, or can relate the terms to the table headings (Figure 1) or IFC concepts (Figure 3). Such synonyms can be provided for locations, products, activities and roles. Within a specific project, there may further synonyms, for example 'SE1' may be synonymous with 'Simon Engineer' or 'se1@enginering.com'. Both the general and the project dictionary can be held as RASE documents (figure 6), or in a database service.

eng-GB: Site engineer	**eng-GB: Site engineer**
Uniclass: Ro_50_20_11	**Uniclass: Ro_50_20_11**
P101: SE1	**P101: SE1**
IFC: IfcActorRole.Engineer	**IFC: IfcActorRole.Engineer**

Figure 6: Example dictionary entry

Experiments

Two scenarios were investigated. In each, the site diary and site monitoring data streams were available as separate timelines. These were provided by the participants as anonymised examples based on actual site data. The site diary is maintained by the site supervisor, logging the significant events. Many site-based ('field') and construction management solutions offer applications to support this activity, including AI-supported voice-and video recording. Site monitoring is dependent on the use of electronic tagging of individuals via their construction hard-hats and vehicles via secure attachments. The specific application used also supported the representation of polygonal safety zones defined from 4D BIM or other inputs.

Some safety issues were detectable by considering a data stream alone. In experiment 1, site monitoring can create a timeline where checking Clause 22(4) can detect if work is being conducted in an excavation. There is a vehicle incursion into the excavation zone, which is detected by the site monitoring. This is event is defined as potentially affecting the stability of the excavation, but work continues, so immediately the rule-engine reports that the site is non-compliant because although a visit by the site engineer has been detected, no acceptance can be sensed (Figure 7).

In experiment 2, the number of aspects that can be checked for compliance expands considerably by combining data streams. In this second scenario, a shift starts, there is a fall of earth and so supports are installed. Supplying the rule-engine with a combined data stream from the site diary and the site monitoring highlights that the excavation was compliant up until the supports were installed but before the excavation had been inspected. Once inspected and approved, the excavation reverts to being compliant (Figure 8).

Overall, two experiments using the live collation of information were used to assess the compliance of a construction site. Alerts have been generated when the excavation is in a non-compliant state. Any alert can be supplied to the site supervisor, site engineer and/or the operatives concerned. These alerts are exactly defined by the sense of the original regulatory text, and potential remedies are suggested.

1: Location		2: Product		3: Activity			4: Actor		CDM	
Name	Description	Name	Description	Name	Description	Date and Time	Name	Description	Compliant	Description
EX1	Excavation	-	-	IN1	Introduction	16/11/2023 09:10	CW1	Crew	TRUE	work in progress
EX1	Excavation	-	-	IN4	Introduction	16/11/2023 10:05	LR1	Lorry	FALSE	stability risk not inspected or satisifed
EX1	Excavation	-	-	VW2	Inspection	16/11/2023 11:00	SE1	Engineer	FALSE	stability risk inspected but satisifed

Figure 7: Non-compliance detected but unresolved from site monitoring alone (experiment 1)

1: Location		2: Product		3: Activity			4: Actor		CDM	
Name	Description	Name	Description	Name	Description	Date and Time	Name	Description	Compliant	Description
S1	Site	B1	Facility	45246	Shift	16/11/2023 08:00	-	-	TRUE	
EX1	Excavation	-	-	IN1	Introduction	16/11/2023 08:10	CW1	Crew	TRUE	excavation but no supports or battering in use
EX1	Excavation	-	-	IN2	Introduction	16/11/2023 08:15	EX1	Excavator	TRUE	excavation but no supports or battering in use
EX1	Excavation	-	-	VW1	Inspection	16/11/2023 08:25	SE1	Engineer	TRUE	excavation but no supports or battering in use
EX1	Excavation	-	-	AP1	Approval	16/11/2023 08:35	SE1	Engineer	TRUE	excavation but no supports or battering in use
EX1	Excavation	-	-	EV1	Landslip	16/11/2023 08:47	CW1	Crew	TRUE	excavation but no supports or battering in use
EX1	Excavation	-	-	NT1	Notification	16/11/2023 08:50	SE1	Engineer	TRUE	excavation but no supports or battering in use
EX1	Excavation	-	-	VW2	Inspection	16/11/2023 09:00	SE1	Engineer	TRUE	excavation but no supports or battering in use
EX1	Excavation	BA1	Battering	IN3	Introduction	16/11/2023 09:05	CR1	Crew	FALSE	material fall but not inspected or satisfied
EX1	Excavation	-	-	AP2	Approval	16/11/2023 09:20	SE1	Engineer	TRUE	excavation inspected and satisifed
EX1	Excavation	-	-	OT1	Removal	16/11/2023 09:30	EX1	Excavator	TRUE	excavation inspected and satisifed

Figure 8: Non-compliance detected and resolved from combined sources (experiment 2)

Temporary non-compliance (in the examples a matter of minutes) may be felt to be too strict. There is no guidance or common knowledge as to what period of time is reasonable before compliance is to be re-established. Reasonableness will depend on what action is attached to the lapse. If an alert sounds on a mobile device, then 5 minutes might be appropriate. If a siren or alarm sounds, then a longer period may be more appropriate.

Discussion

This paper has addressed the question of how rules for the continuous assessment of safety compliance within a site context can be obtained and made operable explicitly and without specific coding. The experiments have shown that some clauses of the C(D&M) 2015 regulations can be assessed in 'real-time', but others may be problematic as they lack 'decidability' due to the temporality of the evaluated processes.

Decidability

Zhang et al. (2022) identified four kinds of ambiguity in normative text which pose obstacles for decidability in automated compliance checking. These are (1) intentional, (2) grammatical, (3) tacit knowledge and (4) domain-specific. A dictionary can hold the collective tacit knowledge, domain-specific mappings and agreed analytic tools to address these obstacles (Beach et al., 2023). In addition, some C(D&M) clauses are ambiguous if taken as metrics defined by examination of the information sources, but if read as objectives, defined by satisfying subsequent clauses, these can be evaluated. We can distinguish testable metrics from objectives, even if their appearance in source regulations appear similar. Previous assumptions about the exclusion of clauses by consideration of the internal characteristics have been replaced with criteria relating to this external context.

Table 1: Obstacles to decidability

Obstacle	Description (and resolution)	*C(D&M) 2015 examples*
Grammar	Two or more possible parsings (resolved by mark-up).	*'work equipment or material'* *(see 22(3))*
Ambiguity	Two or more assessment methods (resolved in dictionary).	*'adjacent'* *(see 22(1))*
Subjectivity	No common assessment method.	*'practicable'* *(see 22(1))*
Objective	Dependant on following sections and metrics (resolved by mark-up or omission).	*'danger'* *(see 22(1))*
Temporality	No information or authority available.	

Thus, decidability is dependent on managing grammar, ambiguity, subjectivity and additionally 'objectives' and 'temporality' (Table 1). Grammatical ambiguity can be resolved by domain experts when performing the RASE markup. In the example it could be that either all material or only work material is meant. Other ambiguities need to be resolved by developing the intermediate dictionary so that there is a common and singular matching of regulatory and descriptive/narrative models, for example 'adjacent' is untestable unless the dictionary provides a plausible distance. Subjectivity, for example 'practicable', arises where perceptions can differ completely between applicant and inspector. This identification of sections as objectives can be resolved by mark-up or its omission. On the other hand, 'temporality' depends on the distinction between leading and live indicators of the state of the construction site as opposed to trailing outcomes such as 'buried or trapped' in clause 22(1c) (Table 2).

Table 2: Safety and compliance indicators

Category	Description	*Safety examples*	*C(D&M) 2015 examples*
Leading indicators	Predictive metrics	*Safety management underway*	*Clauses 1-15*
Live indicators	Direct metrics	*Inspections and satisfactions*	*Clauses 16-35*
Trailing indicators	Outcome metrics	*Safety records and evidence*	*Clause 22(1c)*

Leading and live indicators may be available from documentation or from contemporaneous recordings by sensors and participants. These sources can be combined in a unified information model accessible to a rule engine.

Trailing outcomes are frequently referred to in the first sub-clause in each C(D&M) clauses 16-35. The construction of such sentences gives them a similar appearance to 'actual' requirements, the difference being that the value of the individual metrics is knowable only in retrospect. These can be handled either by deliberately not marking them up or by developing a 'Future World Assumption' (FWA) that requirements and exceptions may be taken as positive but applicability and selections may be taken as negative, at least until they become knowable.

Within in the DRSM (design science research method) framework, the evaluation of the user acceptance of the outcomes is postponed until the artefact has been developed. Such evaluation would need to take into account a number of different organisation contexts into which a live compliance checking system could fit, such as private to the constructor, private to the inspectorate or accessible to both the constructor and inspectorate.

Conclusions

Automated compliance checking has previously been focused on static descriptions of a facility. This work has shown that the RASE methodology can be extended to capture the expectations for dynamic contexts such as construction sites, especially the relative timing of separate requirements. Using a suitable ontology to track real-time events can structure the increasing availability of real-time information on construction sites so as to support the continuous assessment of compliance, such as safety compliance. Definitions of compliance may mix leading, live and trailing metrics which can affect the 'decidability' of those rules. The decidability of individual metrics within regulations depends on addressing ambiguity, subjectivity and especially the 'temporality' of information availability. Whilst the other barriers can be resolved (as listed in Table 1), the use of metrics having trailing 'temporality' can only be resolved by treating these as 'objectives'. This represents a contribution to the real-team process compliance checking in construction.

A limitation of this work has been the limited choice of clauses as examples, and the limited number of information sources used. Further research could be less selective about the clauses considered so as to confirm the completeness of the approach used here. Other leading and real-time information sources, such progress charts, could be integrated.

Further work is being proposed to broaden the number of use-cases supported by the mark-up of construction regulations. This could include decision support tools and educational and training experiences.

Acknowledgments

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