

NOZEL

Jurnal Pendidikan Teknik Mesin

Jurnal Homepage: https://jurnal.uns.ac.id/nozel

RECONSTRUCTING BATTERY THERMAL MANAGEMENT COMPETENCIES FROM OCCUPATIONAL STANDARDS FOR VOCATIONAL EDUCATION IN ELECTRIC VEHICLE TECHNOLOGY

Rusdi Febriyanto[1*], Ananda Yhuto Wibisono Putra[1], and Ricky Cahyasari Putra[1]

[1]Department of Mechanical Engineering Vocational Education,
Universitas Sultan Ageng Tirtayasa, Indonesia
Corresponding e-mail: rusdi.febriyanto@untirta.ac.id

Abstract

Battery Thermal Management System (BTMS) is a safety-critical subsystem of electric vehicle technology, yet it is not established as a named competency unit in the Indonesian National Work Competency Standards (SKKNI) for electrified light vehicle service. Starting from seven BTMS-relevant units identified among the 21 SKKNI units, this study reconstructs their occupational requirements into a competency architecture for vocational education. A qualitative document analysis with deductive content coding was applied to seven units containing 19 competency elements, 118 criteria of competency achievement, 35 knowledge requirements, 21 skill requirements, and 10 critical aspects. The requirements were coded into six functional dimensions: thermal system preparation and technical documentation, thermal condition diagnosis, coolant circuit maintenance, thermal component intervention, high voltage electrical safety, and thermal event emergency response. The analysis showed that BTMS competence is an emergent cross-unit construct formed by three Core units and four Supporting units. Coverage was asymmetric, with preparation and documentation (31.4%), high voltage safety (27.1%), and thermal diagnosis (24.6%) accounting for 83.1% of coded requirements, while coolant circuit maintenance represented 4.2%. The six dimensions were translated into competency clusters with learning outcomes, practical activities, and assessment indicators and organized into a proposed instructional architecture. The findings indicate that occupational standards provide a traceable basis for BTMS procedural competence but require complementary thermal engineering knowledge for conceptual understanding. As a document-based analysis, the findings describe what the standard contains rather than workshop practice and require external validation. The resulting architecture can support curriculum sequencing, assessment design, and modular learning in electric vehicle vocational education.

NOZEL, Volume 09 Nomor 03, Agustus 2027, 284 - 304
https://doi.org/10.20961/nozel.v9i3.128388

Keywords: *competency architecture, occupational standard, battery thermal management, electric vehicle, vocational curriculum, curriculum alignment*

A. INTRODUCTION

The global transition towards electrified road transport has shifted the technological center of gravity of the automobile from the internal combustion engine to the high voltage traction battery (International Energy Agency [IEA], 2024). In an electric vehicle (EV), the battery pack determines range, charging behavior, cost, and, most critically, safety. Lithium ion cells are, however, strongly temperature dependent. Their capacity, internal resistance, cycle life, and failure behavior vary sharply outside a relatively narrow operating window, and both excessive heat and sub-zero operation degrade performance (Kim, Oh, & Lee, 2019; Wang, Jiang, Li, & Yan, 2016). The subsystem responsible for keeping the pack inside that window is the Battery Thermal Management System (BTMS).

Engineering research on BTMS has expanded rapidly. Reviews have compared air cooling, liquid cooling, phase change material cooling, heat pipe cooling, thermoelectric cooling, and refrigerant based architectures, and have evaluated them against maximum cell temperature and temperature uniformity criteria (Kim et al., 2019; Liu, Wei, He, & Zhao, 2017; Mali, Saxena, Kumar, Kalam, & Tripathi, 2021; Rao & Wang, 2011). Coolant selection and cooling strategy have likewise been shown to influence pack level thermal behavior substantially (Akinlabi & Solyali, 2020; Deng et al., 2018). Running through this literature is the problem of thermal runaway, the self-accelerating exothermic chain that can propagate from a single abused cell to the entire pack and produce venting, smoke, and fire (Feng et al., 2018).

The consequences of this shift reach beyond design engineering and into the service workshop. A technician working on an electrified vehicle is no longer only a mechanical problem solver; that technician now handles a high voltage energy store whose condition must be judged, whose cooling circuit must be maintained, and whose failure modes may be thermal and electrochemical rather than purely mechanical. Indonesia has committed to accelerating battery electric vehicle adoption through Presidential Regulation Number 55 of 2019 (Republik Indonesia, 2019), and the resulting service population requires a workforce with verified competence in high voltage and thermal work. The occupational reference for that workforce is the Indonesian National Work Competency Standards, or Standar Kompetensi Kerja Nasional Indonesia (SKKNI), for Light Vehicle Service in the

Electrified Vehicles field, established through the Decree of the Minister of Manpower Number 8 of 2024 (Kementerian Ketenagakerjaan Republik Indonesia, 2024), which contains 21 competency units coded C.29SEV.

For vocational education, SKKNI functions as the bridge between occupational practice and curriculum. Competency based education derives its legitimacy precisely from this alignment: learning outcomes, learning experiences, and assessment are expected to be traceable to occupational performance requirements (Gervais, 2016; Mulder, Weigel, & Collins, 2007). Indonesian studies reflect the same logic in practice, with the SKKNI unit serving as the design primitive from which standard-referenced curricula are assembled (Putra, Febriyanto, & Putra, 2027). Yet the literature on competency based vocational education also warns that decomposing work into discrete competency statements can fragment the underlying knowledge, producing graduates who can execute procedures but cannot reason about the system behind them (Billett, 2011; Wheelahan, 2015). Any translation of a competency standard into a curriculum therefore requires more than transcription; it requires interpretation and reassembly.

This is where a specific gap appears. BTMS does not exist as a named competency unit anywhere in SKKNI Number 8 of 2024. There is no unit entitled battery thermal management. Instead, the requirements that a technician would actually need in order to perform thermal work on an EV battery are scattered: some live in the cooling system maintenance unit, some in the diagnosis unit, some in the high voltage battery replacement unit, and some in units concerned with electrical safety and emergency handling. The existing body of BTMS scholarship is overwhelmingly engineering oriented and does not address how these requirements should be organized for teaching, while the vocational education literature on electric vehicles tends to treat high voltage safety or general EV servicing as the unit of analysis rather than thermal management specifically. As a result, a curriculum developer who wishes to teach BTMS in a vocational program has no systematic account of where the relevant occupational requirements are located, how they relate to each other, or how densely each aspect of thermal work is actually covered by the national standard.

To avoid purposive selection of apparently relevant units, a previously published study (Febriyanto et al., 2026) screened all 21 SKKNI units with a predefined relevance rubric

and retained seven units, a selection that remained stable across alternative thresholds. Whereas the earlier study identified and screened the relevant units, the present study takes that documented seven-unit corpus as its starting point, does not repeat the screening, and asks how the occupational requirements within that corpus can be structurally reorganized into a coherent competency architecture for vocational curriculum design. Three research questions guide the analysis. First, how are the occupational requirements contained in the seven BTMS-relevant units distributed across the functional dimensions of thermal management work? Second, what structural relationship connects the Core and Supporting units, and what does that relationship reveal about the nature of BTMS competence within an occupational standard that contains no unit of its own for it? Third, how can the resulting functional dimensions be translated into competency clusters, learning outcomes, practical activities, and an instructional sequence for vocational education? The study contributes a competency architecture, traceable to the underlying occupational requirements, that curriculum developers, instructors, and assessors can use to sequence BTMS learning and design modular assessment, and it identifies where the national standard alone is insufficient as a content source.

B. METHOD

This study used a qualitative document analysis design and constitutes a second-order analysis of a corpus already established through prior systematic screening (Febriyanto et al., 2026). Document analysis is a systematic procedure for reviewing and evaluating documents in order to elicit meaning and develop empirical knowledge, and it is appropriate when the object of study is itself a text that carries institutional authority (Bowen, 2009). Because the analytical categories were derived in advance from the functional logic of thermal management work, the coding followed a deductive or directed content analysis approach (Elo & Kyngäs, 2008; Krippendorff, 2018).

Data Source and Unit of Analysis

The data source was a single authoritative document: the Decree of the Minister of Manpower of the Republic of Indonesia Number 8 of 2024 (Kementerian Ketenagakerjaan Republik Indonesia, 2024) concerning the establishment of SKKNI for the Light Vehicle Service field, Electrified Vehicles, which specifies 21 competency units. The seven-unit analytical corpus was taken from the systematic relevance screening of all 21 units reported by Febriyanto et al. (2026), summarised in the next subsection. The seven retained units

are listed in Table 1, and the full 21-unit scoring matrix is reported in the earlier study and is not reproduced here. Each retained unit was read in full, including its unit description, competency elements, criteria of competency achievement (kriteria unjuk kerja, abbreviated KUK), variable limitations (batasan variabel), assessment guidance, required knowledge and skills, required work attitudes, and critical aspects. The primary unit of analysis was the individual KUK statement, since the KUK is the smallest performance claim in the standard and is the level at which assessment is actually conducted. Knowledge items, skill items, work attitudes, and critical aspects were treated as secondary units of analysis.

Corpus Screening and Selection

Corpus screening was carried out in the earlier study (Febriyanto et al., 2026), in which all 21 competency units were scored before any unit was selected for detailed analysis. The six indicators were defined as follows: R1, high-voltage battery relevance; R2, thermal/cooling relevance; R3, diagnostic relevance; R4, high-voltage battery safety relevance; R5, BTMS work prerequisite; and R6, discharge/emergency relevance. Scores of 0, 1, and 2 represented not related, indirectly related, and directly related, respectively. The primary threshold was RS ≥ 6, equivalent to 50% of the maximum score of 12, and the selection remained unchanged at RS ≥ 5 and RS ≥ 4 in the sensitivity analysis of the earlier study. Table 1 reproduces only the seven retained units with their relevance scores, to document the corpus adopted here; the scores of the 14 excluded units are reported in the earlier study.

Table 1. The seven SKKNI units retained for BTMS analysis (summarised from Febriyanto et al., 2026)

No.	Unit code	Unit title	R1–R6	RS	Decision
4	C.29SEV01.004.1	Isolating the HV main safety device	1/0/1/2/2/0	6	Include
5	C.29SEV01.005.1	Reading the EWD and Repair Manual for EV	1/1/1/1/2/0	6	Include
6	C.29SEV01.006.1	Performing diagnosis on EV	1/0/2/1/2/0	6	Include
9	C.29SEV03.001.1	Cooling-system maintenance on EV	2/2/1/1/1/0	7	Include
11	C.29SEV04.001.1	HV battery replacement	2/2/1/2/1/0	8	Include
12	C.29SEV04.002.1	HV battery discharge	2/0/0/2/1/2	7	Include
13	C.29SEV04.003.1	HV battery emergency handling at the dealer	2/0/0/2/0/2	6	Include

Note. R1–R6 = relevance indicators; RS = relevance score. Scores are 0 = not related, 1 = indirectly related, and 2 = directly related. Primary inclusion threshold: RS ≥ 6. Source: Febriyanto et al. (2026).

Research Procedure

The analysis proceeded in four stages, summarized in Figure 1. In the first stage, the seven units retained by the previously published screening (Febriyanto et al., 2026) were adopted as the analytical corpus and the unit of analysis was defined. In the second stage, the retained corpus was coded deductively into six BTMS functional dimensions. In the third stage, the coded requirements were reconstructed into a competency architecture using explicit structural rules. In the fourth stage, the resulting architecture was translated into instructional constructs.

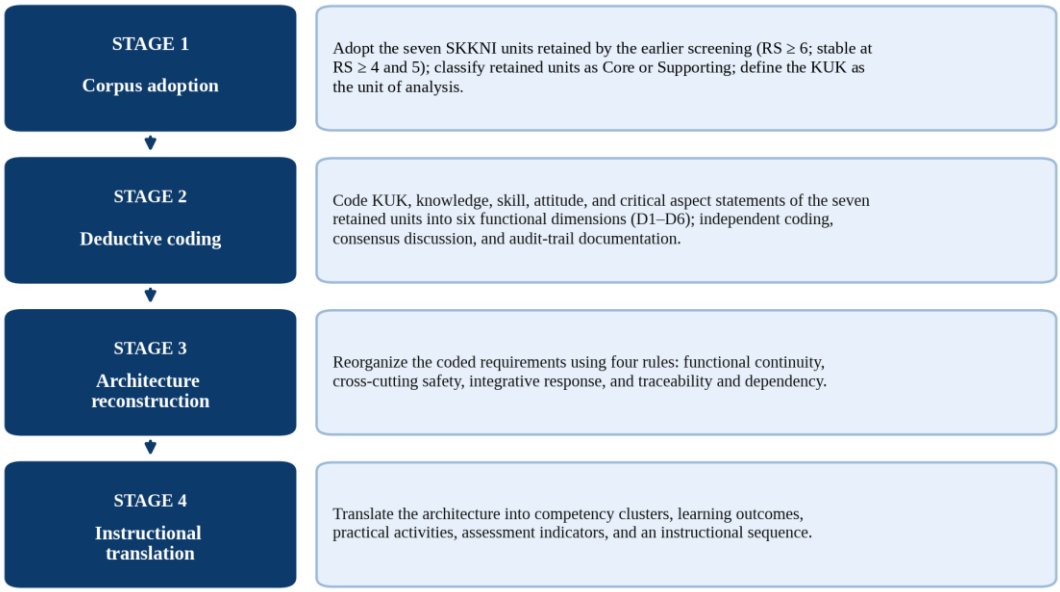


Figure 1. Stages of the document analysis procedure

Corpus screening and selection were completed before the architectural coding and are reported in Febriyanto et al. (2026); they are not repeated here as a finding of this study. That procedure made the transition from the full 21-unit SKKNI to the seven-unit analytical corpus explicit and auditable. The Core and Supporting classification of the retained units follows the same earlier study and is used here as the occupational layer of the architecture. A unit was classified as Core when its primary object of work was the thermal system or the high-voltage battery in a thermal-management context, so that its performance criteria operate directly on thermal conditions or thermal-system components. A unit was classified as Supporting when it supplied an enabling, prerequisite, or safety function required for BTMS work but its primary object of work was not the thermal system itself. The seven

adopted units are listed with this classification, and with their structural profile, in the first subsection of the Results and Discussion.

Coding Framework

The second stage coded every KUK statement of the retained corpus, together with the knowledge, skill, attitude, and critical aspect statements, into one of six BTMS functional dimensions. The dimensions were derived from the functional logic of thermal management work in a service context. D1–D4 represent the main functional pathway from system literacy and diagnosis through coolant maintenance to component intervention; D5 is treated as a cross-cutting high-voltage safety requirement that applies throughout the pathway; and D6 is treated as an integrative emergency capability that draws on the preceding competencies. Table 2 presents the coding framework with operational definitions and an illustrative indicator drawn from the standard.

Table 2. Coding framework of the six BTMS functional dimensions

Code	Dimension	Operational definition	Illustrative indicator from SKKNI
D1	Thermal system preparation and technical documentation	Identification of vehicle and battery type, cooling material, work procedures; preparation and interpretation of the Repair Manual and Electrical Wiring Diagram; selection of tools and equipment	Vehicle type and cooling material are identified (C.29SEV03.001.1, KUK 1.1)
D2	Thermal condition diagnosis and monitoring	Operation of the scan tool, reading of Diagnostic Trouble Codes, data list analysis, comparison with standard values, active testing, and identification of abnormality indicators	Data list values are compared with the Repair Manual standard (C.29SEV01.006.1, KUK 4.2)
D3	Coolant circuit maintenance	Leak inspection, coolant replacement, maintenance of hoses, pipes, radiator and radiator cap, confirmation and reporting of the maintenance result	Cooling system leak inspection is carried out according to procedure (C.29SEV03.001.1, KUK 2.1)
D4	Thermal component intervention	Physical inspection, removal, storage and installation of the high voltage battery, handling of cooling material, leak testing, module balancing and new part setting	The high voltage battery is removed according to procedure (C.29SEV04.001.1, KUK 2.8)
D5	High voltage electrical safety	Application of K3L and 5R procedures, disconnection of the main safety, current leakage and insulation checks, confirmation of the absence of high voltage current, insulated personal protective equipment, dedicated EV stall	The disconnection or absence of high voltage current in the circuit is ensured (C.29SEV01.004.1, KUK 2.8)

Code	Dimension	Operational definition	Illustrative indicator from SKKNI
D6	Thermal event and emergency response	Emergency procedure identification, isolation of the main high voltage cable, cleaning of leaking electrolyte, management of ignition and vapour hazards, and incident documentation	Leaking electrolyte fluid is cleaned according to procedure (C.29SEV04.003.1, KUK 2.4)

Architecture Reconstruction Rules

The third stage reconstructed the competency architecture from the coded requirements using four explicit rules. First, functional continuity: requirements serving the same occupational function were grouped into a coherent dimension, with D1–D4 forming the principal service pathway. Second, cross-cutting safety: requirements that condition the safe performance of multiple functions were treated as a cross-cutting layer rather than as a single sequential phase; this applies to D5. Third, integrative response: emergency requirements that presuppose recognition of normal conditions, system reading, and high-voltage isolation were positioned as an integrative capability; this applies to D6. Fourth, traceability and dependency: every proposed competency cluster had to remain traceable to its source unit and coded requirements, while prerequisite relationships were used to determine the instructional sequence. These rules distinguish the reconstructed architecture from a simple thematic grouping and make the transition from occupational requirements to curriculum constructs explicit.

Trustworthiness and Data Analysis

Coding was performed independently by two of the authors and then reconciled in a consensus discussion; the remaining author audited the reconciled coding against the source text. Every coded item retains a reference to its unit code and KUK number, so the coding decision can be traced back to the standard. When a statement contained more than one functional action, the dominant occupational purpose was used as the primary coding criterion; ambiguous cases were discussed until consensus was reached and recorded in the coding audit trail. Frequencies were then computed for each dimension and each unit, and the quantitative pattern was interpreted qualitatively against the substantive content of the statements. Frequencies are reported as indicators of coverage density within the standard, not as measures of pedagogical importance.

C. RESULTS AND DISCUSSION

Occupational Corpus and Structural Basis of the Competency Architecture

The seven-unit occupational corpus contains 19 competency elements, 118 criteria of competency achievement, 35 knowledge requirements, 21 skill requirements, and 10 critical aspects. Table 3 presents its structural profile and the Core and Supporting classification that forms the starting basis for the competency architecture.

Table 3. Profile and relevance classification of the seven BTMS-related competency units

Unit code	Unit title	EK	KUK	K	S	CA	Level	Basis of relevance
C.29SEV03.001.1	Cooling System Maintenance on Electrified Vehicles	2	14	6	3	1	Core (very high)	Explicit thermal reference and thermal object
C.29SEV01.006.1	Diagnosis on Electrified Vehicles	5	25	5	2	2	Core (high)	Thermal object and condition judgment
C.29SEV04.001.1	High Voltage Battery Replacement	3	24	8	7	2	Core (high)	Thermal object and cooling material handling
C.29SEV04.003.1	Emergency Handling of the High Voltage Battery at the Dealer	2	10	5	5	1	Supporting (high for thermal events)	Thermal event and enabling requirement
C.29SEV01.005.1	Reading the Electrical Wiring Diagram and Repair Manual	3	16	3	0	2	Supporting (moderate to high)	Enabling requirement for system reading
C.29SEV01.004.1	Disconnecting the Main Safety of the High Voltage Circuit	2	18	4	2	1	Supporting (moderate to high)	Safety prerequisite
C.29SEV04.002.1	High Voltage Battery Discharge	2	11	4	2	1	Supporting (moderate)	Battery safety and preparation
Total		19	118	35	21	10		

The structure is layered rather than flat and is represented in Figure 2. At the occupational layer, three Core units carry the substantive thermal work, while four Supporting units provide enabling, prerequisite, or safety functions. At the functional layer, D1–D4 form the principal service pathway; D5 operates as a cross-cutting high-voltage safety requirement throughout that pathway; and D6 represents an integrative emergency capability. This layered relationship is the basis for the reconstructed architecture.

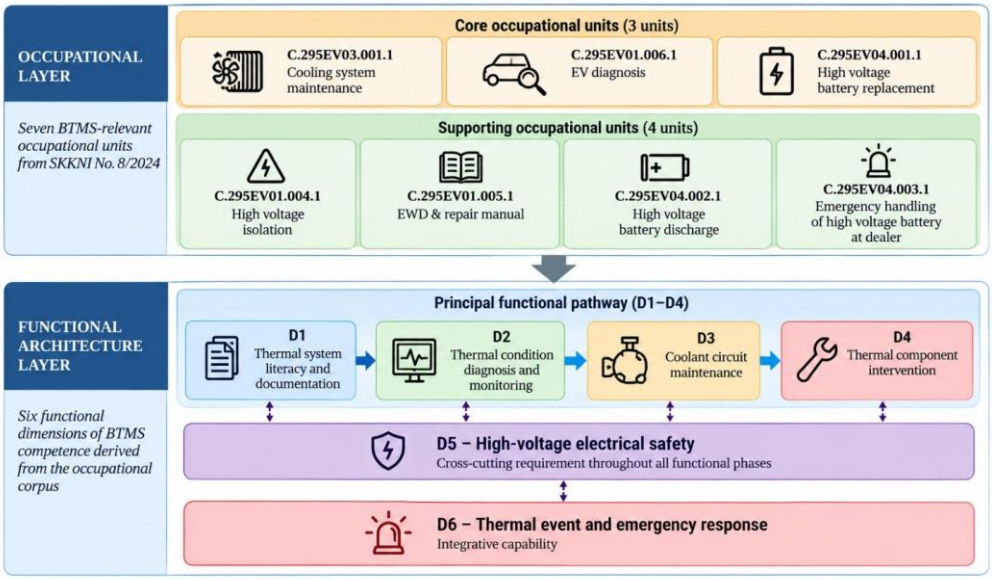


Figure 2. Reconstructed BTMS competency architecture from the occupational corpus to functional dimensions

The first substantive finding is therefore that BTMS competence in the Indonesian standard is an emergent construct rather than a discrete one. It has no unit of its own; its requirements are distributed across the seven-unit corpus and become coherent when these occupational requirements are reconstructed into functional dimensions. For curriculum development, this means that a one-to-one mapping of the identified competency units to separate subjects would not fully represent the cross-unit structure of BTMS competence revealed by the analysis. An integrative learning structure is therefore more consistent with the occupational architecture because no single unit delivers the full capability on its own.

Location of the Thermal Content within the Core Units

Reading the Core units at the level of their elements and criteria of competency achievement shows where the thermal content is actually located. Table 4 presents the BTMS-relevant elements and representative criteria of the three Core units, including the variable limitations, which in several cases carry more thermal specificity than the criteria.

Table 4. BTMS-relevant competency elements and representative criteria of the three Core units

Unit code	Competency element	Representative criteria of competency achievement	Thermal specificity in the variable limitations
C.29SEV03.001.1	1. Preparing cooling system maintenance; 2. Carrying out coolant and cooling component maintenance	1.1 Vehicle type and cooling material identified; 1.3 Coolant replacement procedure identified; 1.9 Diagnosis result identified as the reference for action; 2.1 Leak inspection conducted; 2.2 Coolant replaced; 2.3 Maintenance action performed	Application explicitly covers maintenance on the high voltage battery, inverter and DC to DC converter, electric motor and generator; cooling media include water, air and oil; leak inspection covers level, pressure, radiator cap, hose and pipe condition
C.29SEV01.006.1	1. Preparing the diagnosis; 4. Analyzing the data list; 5. Checking component working capability	1.4 EV control system identified; 1.6 Diagnostic Trouble Code identified; 1.7 Data list and standard values identified; 4.2 Data list values compared with the Repair Manual standard; 5.2 Active test data analyzed	Required knowledge includes the working principle and characteristics of the high voltage battery; in the cooling system unit the diagnosis result is specified as scanner actuator testing on the coolant fan motor and the electric water pump
C.29SEV04.001.1	1. Preparing the replacement; 2. Removing the high voltage battery; 3. Installing the high voltage battery	1.1 Model and high voltage battery type identified; 2.4 Physical condition of the battery inspected; 2.6 Current leakage inspected with a megaohm tester; 2.8 Battery removed; 3.1 New battery installed; 3.5 New part setting performed	For several EV types the removal procedure includes draining the cooling material before the battery is removed and evacuating refrigerant where it is connected to the battery system; the installation procedure includes battery balancing, refitting the cooling material, leak testing, coolant

Two observations follow. First, the most thermally explicit statements in the seven-unit corpus are not in the criteria of competency achievement but in the variable limitations of the cooling system and battery replacement units. It is there that the standard states that cooling maintenance applies to the high voltage battery, that cooling media include water, air, and oil, and that battery replacement may involve draining and refilling coolant, leak testing, and refrigerant handling. A curriculum developer who reads only the criteria will miss the thermal content almost entirely. Second, the diagnostic pathway to thermal condition runs through generic diagnostic competence: the standard does not prescribe a battery temperature diagnostic procedure, but it does prescribe data list comparison against standard values and actuator testing on the coolant fan motor and the electric water pump, which is functionally the thermal diagnosis pathway available in a workshop.

Distribution across BTMS Functional Dimensions

Coding the 118 criteria of competency achievement into the six dimensions produced the coverage matrix shown in Table 5 and visualized in Figure 3. The 118 criteria are the same as those profiled in Table 3 (row totals match the KUK column). Competency elements (EK) are listed only for reconciliation with Table 3 (19 in total); they are not allocated to dimensions because coding was performed at the level of the individual criterion.

Table 5. Distribution of BTMS-relevant criteria of competency achievement across the six functional dimensions

Unit code	EK	D1	D2	D3	D4	D5	D6	Total
C.29SEV03.001.1 (Core)	2	6	1	5	0	2	0	14
C.29SEV01.006.1 (Core)	5	1	22	0	1	1	0	25
C.29SEV04.001.1 (Core)	3	5	2	0	8	9	0	24
C.29SEV04.003.1 (Supporting)	2	2	0	0	0	2	6	10
C.29SEV01.005.1 (Supporting)	3	13	2	0	0	1	0	16
C.29SEV01.004.1 (Supporting)	2	6	2	0	0	10	0	18
C.29SEV04.002.1 (Supporting)	2	4	0	0	0	7	0	11
Total	19	37	29	5	9	32	6	118
Percentage	–	31.4	24.6	4.2	7.6	27.1	5.1	100

Note. D1 = preparation and documentation; D2 = thermal diagnosis; D3 = coolant circuit maintenance; D4 = thermal component intervention; D5 = high voltage safety; D6 = thermal event emergency; EK = competency elements (not distributed across dimensions); Total = criteria of competency achievement (KUK).

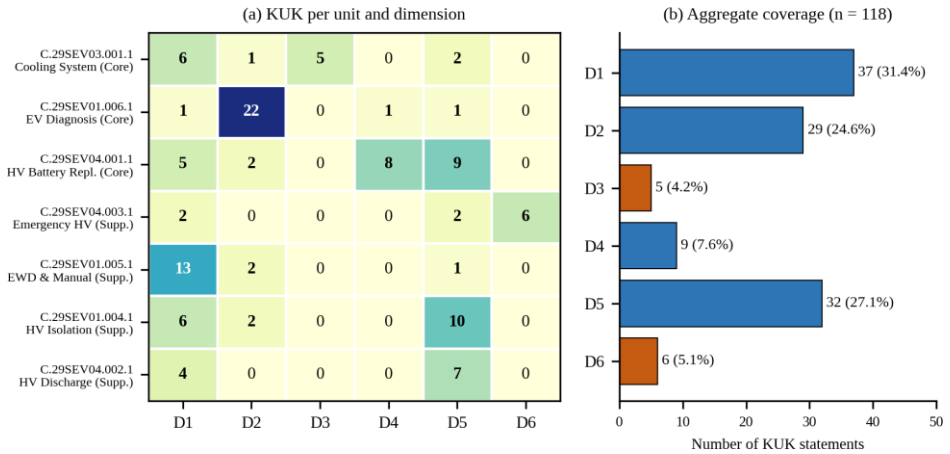


Figure 3. Distribution of BTMS-relevant criteria of competency achievement: (a) per unit and functional dimension; (b) aggregate coverage (n = 118)

The distribution is strongly asymmetric, and the asymmetry is the second substantive finding. Preparation and documentation (31.4%), high voltage safety (27.1%), and thermal diagnosis (24.6%) together account for 83.1% of all coded requirements. Direct coolant circuit maintenance, which is the operational heart of thermal management work, accounts for only 4.2%, and thermal event emergency response for 5.1%. This reflects the relatively low textual coverage of direct coolant-circuit and thermal-intervention requirements within the analyzed corpus, rather than to an overall judgment of the occupational standard.

This distribution is better interpreted as a reflection of the purpose of the standard than as a defect. SKKNI is written to certify safe and procedurally correct workshop conduct, and in a high-voltage context the immediate safety emphasis is necessarily strong. The implication for vocational education, however, is that a curriculum derived only from the standard could provide substantial procedural requirements without necessarily providing the explanatory thermal knowledge needed to understand the underlying thermal behavior. This is consistent with the fragmentation risk identified in competency-based education literature, where atomized performance statements may not by themselves provide the systematic knowledge that makes performance intelligible (Mulder et al., 2007; Wheelahan, 2015).

The remedy suggested by this analysis is compositional rather than substitutive. The standard should remain the reference for what graduates must be able to do, while the thermal engineering literature supplies the explanatory layer that the standard omits: heat generation mechanisms in lithium ion cells, the comparative logic of air, liquid, phase change, heat pipe and refrigerant based architectures, and the relationship between temperature uniformity and pack degradation (Kim et al., 2019; Liu et al., 2017; Mali et al., 2021; Rao & Wang, 2011). Coolant selection, which the standard treats as a procedural identification step, is in the engineering literature a design variable with measurable consequences for cooling performance (Akinlabi & Solyali, 2020; Deng et al., 2018).

A related observation concerns thermal runaway. The emergency unit describes, with considerable operational precision, a set of indications that a technician may encounter: secondary ignition of the high voltage battery, causes of fire, the odour of organic vapour,

the acidic odour produced by oxidation of the electrolyte, electric shock, and hissing or popping sounds around the battery. These are, phenomenologically, the observable signature of thermal runaway (Feng et al., 2018). The standard, however, describes the symptoms without naming or explaining the mechanism. Taught as written, the list becomes something to memorize; taught alongside the runaway mechanism, the same list becomes a causal diagnostic reasoning chain. The pedagogical difference between these two outcomes is substantial and costs nothing but the addition of explanatory content.

A third observation is more encouraging for Indonesian institutions with limited laboratory budgets. The single densest cell in the matrix is thermal diagnosis within the EV diagnosis unit, with 22 coded requirements. Diagnostic competence is scan tool based and data driven rather than dependent on a full BTMS test bench. Reading battery temperature data lists, comparing them against Repair Manual standards, and running actuator tests on the coolant fan motor and the electric water pump can be practiced on an instructional trainer or a single service vehicle. The distribution of the standard thus indicates that a large share of BTMS-relevant competence is attainable with modest equipment, provided that scan tools and manufacturer service data are available.

Convergence of Knowledge, Skills, Attitudes, and Critical Aspects

Beyond the criteria of competency achievement, the standard specifies required knowledge, required skills, required work attitudes, and critical aspects. Analyzing how these recur across the seven units reveals which requirements are structural rather than incidental. Table 6 presents the convergence pattern.

Table 6. Convergence of knowledge, skills, attitudes, and critical aspects across the seven units

Category	Requirement stated in SKKNI	Units in which it appears	f
Knowledge	Safety work	All seven units	7
Knowledge	Working principle and characteristics of the high voltage battery	01.006.1; 03.001.1; 04.001.1; 04.002.1; 04.003.1	5
Knowledge	Low voltage and high voltage electricity	01.004.1; 01.006.1; 03.001.1; 04.001.1	4
Knowledge	Product or basic knowledge of electrified vehicles	01.004.1; 01.005.1; 03.001.1; 04.001.1	4
Knowledge	Vehicle cooling system	03.001.1; 04.001.1	2
Knowledge	Characteristics of the cooling material	03.001.1; 04.001.1	2
Knowledge	Hazard potential, storage and handling of the high voltage battery	04.002.1; 04.003.1	2

Category	Requirement stated in SKKNI	Units in which it appears	f
Knowledge	Module balancer	04.001.1; 04.002.1	2
Knowledge	Wiring diagram	01.004.1; 04.003.1	2
Knowledge	High voltage battery waste handling; EV control communication path; emergency diagnosis	04.001.1; 01.006.1; 04.003.1	1
Skill	Using a multimeter	01.004.1; 03.001.1; 04.001.1; 04.003.1	4
Skill	Using a megaohm insulation tester	01.004.1; 04.001.1; 04.003.1	3
Skill	Using a radiator cap tester	03.001.1; 04.001.1	2
Skill	Operating the stall lifter	03.001.1; 04.001.1	2
Skill	Operating the module balancer	04.001.1; 04.002.1	2
Skill	Operating lifting equipment (battery lifter, baby crane)	04.001.1; 04.002.1	2
Skill	Using a fire extinguisher and documenting emergency evidence	04.003.1	1
Attitude	Discipline, precision (cermat), thoroughness (teliti)	All seven units, identically worded	7
Critical aspect	Precision and thoroughness in performing the prescribed action (most), and confirmation of a safe state (some); distributed as D1 (2), D2 (2), D3 (1), D4 (2), D5 (2), D6 (1)	All seven units	10

Three patterns are worth noting. First, safety work is the only knowledge requirement present in all seven units, and the working principle and characteristics of the high voltage battery appear in five. These two items are the knowledge spine of BTMS competence in the standard, and they should accordingly be positioned as foundational content rather than as topics within a single subject. Second, the instrumentation profile is narrow and affordable: a multimeter, a megaohm insulation tester, a radiator cap tester, a stall lifter, a module balancer, and lifting equipment cover the entire skill requirement set. This is an actionable specification for a vocational laboratory. Third, the work attitude requirement is identical across all seven units, and most of the ten critical aspects are phrased in terms of precision and thoroughness in executing a prescribed action, while the others concern confirming a safe state, such as the absence of high-voltage current or an empty battery.

That third pattern has a direct assessment consequence. If most critical aspects in the standard are statements about the quality of procedural execution rather than about the quality of an outcome, then assessment cannot be limited to inspecting the finished product of a practical task. It must observe the process. This calls for observation based rubrics that score procedural fidelity at defined checkpoints, which is also what constructive alignment

would require if the stated learning outcome is procedural competence (Biggs, 1996). The distribution of the ten critical aspects across the dimensions, with at least one in each, further indicates that assessment should sample all six dimensions rather than concentrating on the visible maintenance task.

Translating the Map into Instructional Constructs

The third research question concerns curriculum reconstruction. Grouping the coded requirements by dimension produces six competency clusters, each of which can be expressed as a learning outcome with an associated practical activity, assessment indicator, and architectural role. Table 7 presents this translation.

Table 7. Instructional constructs and architectural roles derived from the competency architecture

Cluster and source units	Architectural role	Proposed learning outcome	Representative practical activity	Assessment indicator
C1. Thermal system literacy and documentation (D1); 01.005.1, 03.001.1, 01.004.1, 04.001.1	Foundational system literacy	Students are able to interpret the Repair Manual and Electrical Wiring Diagram in order to locate the components, fluid routes, and electrical paths of the thermal management system of a given EV model	Guided tracing of the coolant circuit and thermal sensor wiring on the Repair Manual and EWD of a specific model, producing an annotated system diagram	Accuracy in identifying component positions and fluid and electrical routes against the manual, with correct interpretation of technical symbols
C2. Thermal condition diagnosis (D2); 01.006.1	Diagnostic capability	Students are able to diagnose abnormal thermal conditions of the high voltage battery by reading Diagnostic Trouble Codes, data lists, and active test results and comparing them with standard values	Scan tool practice on an EV trainer or service vehicle: reading battery temperature data lists and running actuator tests on the coolant fan motor and the electric water pump	Correctness of the comparison against Repair Manual standard values, of the diagnostic conclusion, and completeness of the diagnostic report
C3. Coolant circuit maintenance (D3); 03.001.1	Thermal maintenance capability	Students are able to inspect, pressure test, and replace the coolant of the EV cooling circuit that serves the high voltage battery according to procedure	Pressure testing with a radiator cap tester; inspection of hoses, pipes, radiator and radiator cap; coolant draining and refilling; confirmation of the result	Procedural fidelity and thoroughness in leak inspection and coolant replacement, with no residual leakage and correct coolant level and specification
C4. Thermal component intervention (D4); 04.001.1	Component intervention capability	Students are able to carry out removal and installation of the high voltage battery including handling of the cooling material, leak testing, and module balancing according to procedure	Simulated removal and installation sequence on a trainer, including draining the cooling material before removal, refilling and leak testing after installation, and new part setting	Correctness of the sequence, verified handling of the cooling material, a successful leak test, and completed initialization or learning of the new part

Cluster and source units	Architectural role	Proposed learning outcome	Representative practical activity	Assessment indicator
C5. High voltage thermal safety (D5); 01.004.1, 04.001.1, 04.002.1	Cross-cutting high-voltage safety	Students are able to secure the high voltage system before any thermal management task by disconnecting the main safety and verifying the absence of high voltage current	Service plug removal drill; insulation and leakage measurement with a multimeter and megaohm tester; use of insulated personal protective equipment and correct EV stall positioning	Verified absence of high voltage current before work begins, complete and correct use of protective equipment, and compliance with K3L and 5R procedures
C6. Thermal event emergency response (D6); 04.003.1	Integrative emergency capability	Students are able to respond to a high voltage battery emergency presenting thermal indications by isolating the main cable, containing electrolyte leakage, and documenting the incident	Scenario based drill on emergency indications such as hissing sounds, organic vapour odour, smoke or secondary ignition, with isolation, selection of extinguishing media, electrolyte cleaning and documentation	Correct recognition of emergency indications, correctness of isolation and containment actions, and completeness of the incident documentation

Note. Source units are those contributing at least five coded criteria to the dimension in Table 5.

The clusters are not merely a list; they imply an architecture for instruction. Figure 4 represents D1–D4 as the principal progression from system literacy through diagnosis and maintenance to component intervention, while D5 is shown as a continuous safety gate and D6 as an integrative emergency capability. This representation follows the explicit reconstruction rules defined in the Method rather than treating all six dimensions as equivalent linear phases.

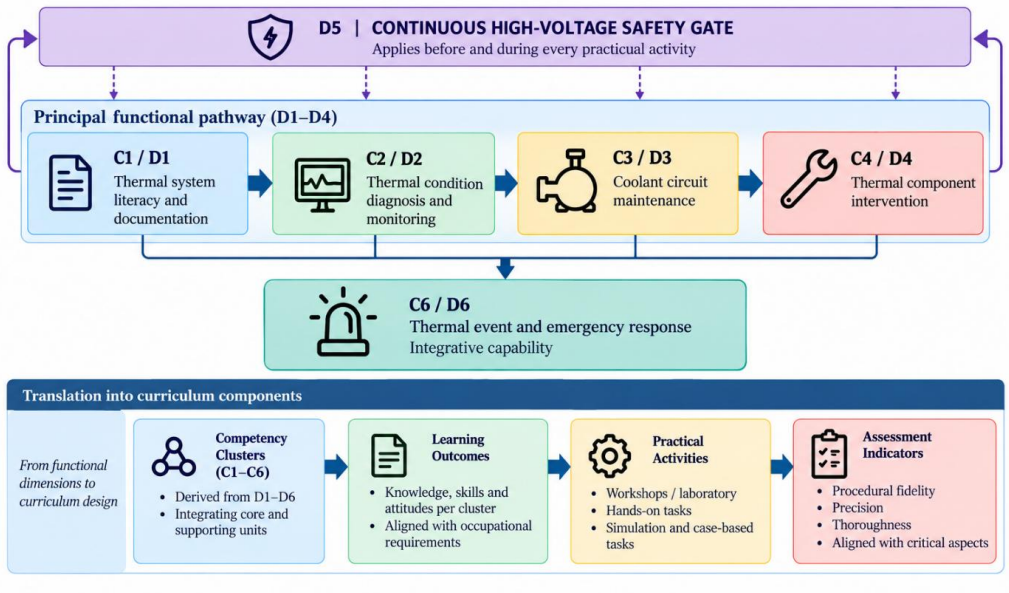


Figure 4. Proposed BTMS curriculum architecture with a D1–D4 functional pathway, continuous D5 safety gate, and integrative D6 emergency capability

Two structural features of the sequence deserve emphasis. The safety gate is continuous rather than a single phase: the K3L and 5R requirement appears across the seven-unit corpus, which means that every practical session in every phase should begin with confirmation that the high-voltage system is safely isolated. The assessment spine is likewise continuous, since the ten critical aspects are distributed across all six dimensions. Emergency response is positioned as an integrative capability rather than simply as the final chronological topic because a meaningful emergency drill presupposes that learners can recognize normal thermal behavior, read the system, and secure the high-voltage circuit.

The cluster structure also provides a potential basis for modular certification. Each cluster is defined by a coherent functional role, is traceable to identified units of the national standard, and carries its own assessment indicator. This structure could support stackable micro-credentials (Kato, Galán-Muros, & Weko, 2020), subject to external validation of the clusters and assessment requirements, rather than assuming that the present document analysis alone establishes certification validity. A four-stage pathway for SKKNI-referenced micro-credentials, comprising decomposition of SKKNI units, outcome formulation, verifiable credentialing, and KKNI levelling, has been proposed on the basis of a systematic review (Putra, Febriyanto, & Putra, 2027); the clusters reported here could serve as input to its decomposition stage.

Limitations

Several limitations should be acknowledged. The analysis is confined to a single document, so it reports what the national standard contains rather than what workshop practice actually requires; industry practice at authorized EV dealers may exceed or diverge from the standard. The six-indicator relevance scoring is an analytical screening device developed in the earlier study (Febriyanto et al., 2026) and represents researcher judgment; although the threshold was subjected to sensitivity analysis. The assignment of criteria to the six functional dimensions is also interpretive, although it was independently coded and reconciled, and a different coding team might allocate some boundary cases differently, particularly between preparation and safety.

D. CONCLUSION

This study reconstructed the occupational requirements related to battery thermal management in the Indonesian National Work Competency Standards for Light Vehicle Service in the Electrified Vehicles field into a coherent competency architecture. The analysis covered seven BTMS-relevant SKKNI units, comprising 19 competency elements and 118 criteria of competency achievement, which were then reorganized into a functionally differentiated architecture with a D1–D4 pathway, D5 as a cross-cutting safety layer, and D6 as an integrative emergency capability.

Three conclusions follow. First, BTMS competence in the standard is an emergent cross-unit construct rather than a discrete competency unit, so curriculum design should represent the interdependence among the identified requirements rather than reproduce them as isolated instructional subjects. Second, coverage is asymmetric: preparation and documentation, high-voltage safety, and thermal diagnosis account for 83.1% of the coded requirements, while direct coolant circuit maintenance accounts for 4.2%; this indicates that the standard provides a strong occupational reference for procedural performance but should be complemented with explicit thermal engineering knowledge when the aim is conceptual understanding. Third, the reconstructed architecture is translatable into six competency clusters with learning outcomes, practical activities, and assessment indicators, while the predominant emphasis on precision and thoroughness supports observation-based assessment of procedural fidelity.

Reorganizing the SKKNI-based requirements into an explicit competency architecture therefore provides a traceable basis for strengthening alignment between BTMS learning and occupational competency requirements, while also making visible the points at which curriculum developers need to supplement the standard with explanatory thermal knowledge.

Acknowledgment

The authors gratefully acknowledge the support provided by Universitas Sultan Ageng Tirtayasa through the 2026 Internal Research Funding Scheme, Faculty Funding Allocation, under Rector's Decree No. 446/UN43/KPT.HK.02/2026.

REFERENCES

Akinlabi, A. A. H., & Solyali, D. (2020). Configuration, design, and optimization of air-cooled battery thermal management system for electric vehicles: A review. *Renewable and Sustainable Energy Reviews, 125*, 109815. https://doi.org/10.1016/j.rser.2020.109815

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education, 32*(3), 347–364. https://doi.org/10.1007/BF00138871

Billett, S. (2011). *Vocational education: Purposes, traditions and prospects*. Dordrecht, Netherlands: Springer. https://doi.org/10.1007/978-94-007-1954-5

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal, 9*(2), 27–40. https://doi.org/10.3316/QRJ0902027

Deng, Y., Feng, C., E, J., Zhu, H., Chen, J., Wen, M., & Yin, H. (2018). Effects of different coolants and cooling strategies on the cooling performance of the power lithium ion battery system: A review. *Applied Thermal Engineering, 142*, 10–29. https://doi.org/10.1016/j.applthermaleng.2018.06.043

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing, 62*(1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Febriyanto, R., Putra, A. Y. W., Putra, R. C., & Aprilliano, M. I. P. (2026). Mapping battery thermal management competencies for electric vehicle vocational education: An analysis of SKKNI-based requirements. *The 2nd International Conference on Character and Sustainable Education (ICoCSE), 2*, 298–312.

Feng, X., Ouyang, M., Liu, X., Lu, L., Xia, Y., & He, X. (2018). Thermal runaway mechanism of lithium ion battery for electric vehicles: A review. *Energy Storage Materials, 10*, 246–267. https://doi.org/10.1016/j.ensm.2017.05.013

Gervais, J. (2016). The operational definition of competency-based education. *The Journal of Competency-Based Education, 1*(2), 98–106. https://doi.org/10.1002/cbe2.1011

International Energy Agency. (2024). *Global EV outlook 2024: Moving towards increased affordability*. Paris, France: IEA. Retrieved September 28, 2026, from https://www.iea.org/reports/global-ev-outlook-2024

Kato, S., Galán-Muros, V., & Weko, T. (2020). *The emergence of alternative credentials* (OECD Education Working Paper No. 216). Paris, France: OECD Publishing. https://doi.org/10.1787/b741f39e-en

Kementerian Ketenagakerjaan Republik Indonesia. (2024). *Keputusan Menteri Ketenagakerjaan Republik Indonesia Nomor 8 Tahun 2024 tentang Penetapan Standar Kompetensi Kerja Nasional Indonesia Kategori Industri Pengolahan Golongan Pokok Industri Kendaraan Bermotor, Trailer dan Semi Trailer Bidang Servis Kendaraan Ringan Electrified Vehicles*. Jakarta, Indonesia: Kementerian Ketenagakerjaan. Retrieved September 28, 2026, from https://jdih.kemnaker.go.id/peraturan/detail/2433/keputusan-menteri-ketenagakerjaan-nomor-8-tahun-2024

Kim, J., Oh, J., & Lee, H. (2019). Review on battery thermal management system for electric vehicles. *Applied Thermal Engineering, 149*, 192–212. https://doi.org/10.1016/j.applthermaleng.2018.12.020

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology* (4th ed.). Thousand Oaks, CA: SAGE Publications.

Liu, H., Wei, Z., He, W., & Zhao, J. (2017). Thermal issues about Li-ion batteries and recent progress in battery thermal management systems: A review. *Energy Conversion and Management, 150,* 304–330. https://doi.org/10.1016/j.enconman.2017.08.016

Mali, V., Saxena, R., Kumar, K., Kalam, A., & Tripathi, B. (2021). Review on battery thermal management systems for energy-efficient electric vehicles. *Renewable and Sustainable Energy Reviews, 151*, 111611. https://doi.org/10.1016/j.rser.2021.111611

Mulder, M., Weigel, T., & Collins, K. (2007). The concept of competence in the development of vocational education and training in selected EU member states: A critical analysis. *Journal of Vocational Education and Training, 59*(1), 67–88. https://doi.org/10.1080/13636820601145630

Putra, R. C., Febriyanto, R., & Putra, A. Y. W. (2027). Aligning micro-credentials with the Indonesian National Competency Standards (SKKNI) and Qualifications Framework (KKNI) for mechanical engineering education: A systematic review. *NOZEL: Jurnal Pendidikan Teknik Mesin, 9*(2), 178–198. https://doi.org/10.20961/nozel.v9i2.124283

Rao, Z., & Wang, S. (2011). A review of power battery thermal energy management. *Renewable and Sustainable Energy Reviews, 15*(9), 4554–4571. https://doi.org/10.1016/j.rser.2011.07.096

Republik Indonesia. (2019). *Peraturan Presiden Republik Indonesia Nomor 55 Tahun 2019 tentang Percepatan Program Kendaraan Bermotor Listrik Berbasis Baterai (Battery Electric Vehicle) untuk Transportasi Jalan* (Lembaran Negara Republik Indonesia Tahun 2019 Nomor 146). Retrieved September 28, 2026, from https://jdih.kemenkeu.go.id/dok/perpres-55-tahun-2019

Wang, Q., Jiang, B., Li, B., & Yan, Y. (2016). A critical review of thermal management models and solutions of lithium-ion batteries for the development of pure electric vehicles. *Renewable and Sustainable Energy Reviews, 64*, 106–128. https://doi.org/10.1016/j.rser.2016.05.033

Wheelahan, L. (2015). Not just skills: What a focus on knowledge means for vocational education. *Journal of Curriculum Studies, 47*(6), 750–762. https://doi.org/10.1080/00220272.2015.1089942