Development of an Electric Vehicle Technical Training Framework for Malaysian TVET Institutions

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ABSTRACT

The transition to electric mobility creates a workforce development challenge for Malaysian Technical and Vocational Education and Training (TVET) institutions. Automotive training must prepare technicians for high-voltage hazards, electrical systems, and software-based diagnosis while retaining the conceptual knowledge needed to adapt across vehicle platforms. Existing occupational standards and industry partnerships provide a foundation, but the relationship between training progression, demonstrated competence, institutional readiness, and permission to perform specific tasks requires clearer articulation. This conceptual paper proposes an Electric Vehicle Technical Training Framework (EV-TTF) to address that design problem. It uses an interpretive synthesis of selected scholarly literature, policy sources, and international examples of qualifications, informed by competency-based training and its critiques. The approach develops a provisional model rather than reporting a systematic review, stakeholder consensus, or empirical validation. The framework integrates five components: policy and industry alignment; six competency domains; a four-tier vehicle-training pathway; competency-based delivery and assessment; and institutional enabling conditions. Its central design principle is that safety-critical competence constitutes a non-compensatory requirement for progression, while conceptual system knowledge supports transfer across technologies. Qualification attainment is distinguished from task-specific workplace authorization, and charging infrastructure is treated as a related but separate occupational route. Five propositions explain the expected relationships between safety assessment, knowledge transfer, institutional readiness, authorization decisions, and competence maintenance. The framework offers a reference for curriculum planning and institutional review, subject to detailed mapping against current Malaysian standards and regulatory requirements. It offers a context-specific integration of established training principles and identifies an empirical agenda that combines expert review with direct performance assessment. Its practical effectiveness and effects on safety or employability remain to be tested.

Keywords: electric vehicle; TVET; competency-based training; high-voltage safety; workforce development

INTRODUCTION

Background of study

Vehicle electrification changes the knowledge, skills, and workplace responsibilities required of automotive technicians. In addition to mechanical maintenance, electric vehicle (EV) work involves traction batteries, power electronics, electrical diagnosis, and software-controlled systems. These technologies introduce hazards associated with electrical energy, stored energy, and damaged batteries. The level of competence needed therefore, depends on the task being undertaken, ranging from awareness for vehicle handling to specialist competence for work on high-voltage (HV) systems (Health and Safety Executive, 2025). For TVET institutions, the educational challenge is to connect this task-dependent risk with curriculum sequencing, assessment, and the conditions under which practical learning can occur.

Malaysia's electric-mobility agenda includes the Low Carbon Mobility Blueprint, the National Automotive Policy 2020 and the New Industrial Master Plan 2030. These instruments connect vehicle technology, industrial development and workforce preparation (Tham, 2023, 2024). The National TVET Policy 2030 provides a wider institutional context for skills development (AIPA, 2024; RTM, 2023). Their relevance to this paper lies in aligning occupational training with national direction; policy targets are not treated as evidence that a specific curriculum or authorization mechanism is already in place.

Malaysia's transition to electric mobility is supported by industrial policy and investment in vehicles and charging infrastructure. Veza *et al.* (2022) identified opportunities alongside infrastructure and energy-system constraints, while Tham (2024) examined the progress and continuing challenges of the transition. The expansion of EV use creates a reason to plan workforce development, but market growth alone does not establish the magnitude of a technician shortage. That magnitude would require comparable data on the vehicle fleet, workload, workforce competence and regional training capacity. This paper, therefore, uses the EV transition as context for a training-design problem rather than as proof of a quantified national skills deficit.

Problem statement

The development of EV-related National Occupational Skills Standards (NOSS) and training initiatives indicates a policy response to workforce needs (Kosmo, 2023; RTM, 2026). However, counts of people certified under a particular scheme do not capture all technicians trained through OEMs, private providers or other qualifications. Historical certification counts are therefore not treated here as estimates of the current competent workforce. The problem addressed is how existing standards and provisions can be connected to a transparent sequence of learning, demonstrated performance, and task-specific permission to work.

Three design issues emerge from the selected literature. First, Malaysian reviews identify challenges in incorporating EV knowledge and skills into automotive programs, including curriculum, instructor, and infrastructure readiness (Azman *et al.*, 2025; Basri *et al.*, 2025). Second, training is delivered through multiple agencies and industry partnerships. Such diversity may improve access and technical relevance, but it also raises questions about comparability and transferability across programs; it does not, by itself, demonstrate inconsistent quality. Third, practical training requires a match between the tasks taught, instructor competence, and facilities suitable for HV work. Evidence from outside Malaysia identifies equipment and collaboration constraints, although the extent of those constraints in Malaysian institutions requires direct investigation (Nursyafti *et al.*, 2026).

Earlier Malaysian automotive studies examined behavioral competence and employability requirements (Abd Samad *et al.*, 2018). Mazlan *et al.* (2025) reported differences in academic and industry agreement on operational skill components in an Industry 4.0 context. Such findings motivate closer examination of how stakeholders define competence, but differences in agreement do not measure actual graduate performance and cannot be assumed to describe EV technicians. They support the inclusion of industry perspectives in framework development rather than proving a national EV competence deficit.

The proposed contribution concerns integration. Recent research already offers institutional implementation and digital teaching frameworks, including a CIPP-based NDT certification model and MyDigCompTVET (Hani, *et al.*, 2026; Mohamad, *et al*., 2026). These studies establish relevant foundations; they do not specify the EV task scopes, high-voltage progression criteria, or vehicle–EVSE boundaries addressed here. The bounded conceptual gap concerns how to integrate these occupational decisions into a single provisional EV training model. EV-TTF therefore adapts established principles rather than claiming novelty for institutional readiness or digital competence itself.

Purpose and research questions

The purpose of this conceptual paper is to propose a provisional Electric Vehicle Technical Training Framework (EV-TTF) for Malaysian TVET institutions, informed by Competency-Based Training (CBT). The framework supports curriculum and implementation decisions; it does not create a qualification, establish legal permission to work or demonstrate training effectiveness. The paper addresses three questions:

1. What competency domains are required for EV technical work in the Malaysian context?

2. How can these competencies be organized into a safe and progressive training pathway that is aligned with the Malaysian skills qualification structure?

3. What delivery, assessment, and institutional conditions are needed, and how should training completion be distinguished from task-specific workplace authorization?

Policy And Industry Context

National policies driving electric mobility

Malaysia's EV agenda is shaped by a set of overlapping policy instruments rather than one single EV law. Table 1 summarizes the policies most relevant to EV workforce development and highlights the talent-related element in each.

Table 1. Key national policies relevant to EV workforce development in Malaysia

Policy	Lead agency	Main EV direction	Talent-related element
Low Carbon Mobility Blueprint 2021–2030	Ministry of Environment and Water / MGTC	EV adoption and charging-infrastructure development	Implicit; focus on adoption and infrastructure
National Automotive Policy 2020	MITI	Shift from Energy Efficient Vehicles to NxGV, MaaS and IR4.0	National Roadmap for Automotive and Mobility Talent (NRAMTa)
New Industrial Master Plan 2030	MITI	EV development within industrial transformation and net-zero priorities	High-skilled workforce as part of the plan's vision
National TVET Policy 2030	National TVET Council (MTVET)	Links TVET to high-growth sectors including EV	National direction for coordinating skills provision
Thirteenth Malaysia Plan (RMK13) 2026–2030	Ministry of Economy	TVET coordination and institutional development	Skills provision and proposed coordination arrangements; implementation status requires current agency confirmation

Sources: Tham (2023); RTM (2026); AIPA (2024); Berita Harian (2025). The table summarises policy directions as contextual information rather than detailed training standards.

These policies establish directions for mobility and industrial development, whereas curriculum implementation requires additional decisions about occupational tasks, prerequisites, assessment and institutional resources. Tham (2023) discusses the role of EV development in NIMP 2030. For the proposed framework, the educational implication is that a national technology priority must be translated into task-level learning and assessment requirements rather than copied directly into a list of course topics.

Public reporting on planned EV TVET programs and standards development indicates policy attention to workforce preparation (Malay Mail, 2023; RTM, 2023). Such announcements should be distinguished from evidence of program coverage and effectiveness. EV-TTF uses the policy context to define a coordination problem and leaves the assessment of actual institutional implementation to subsequent research.

Market growth and infrastructure

The changing EV market reinforces the relevance of workforce planning, but the relationship between vehicle adoption and training demand is mediated by vehicle age, warranty coverage, service intervals, workshop access and the type of work required. The literature on Malaysia identifies both growth opportunities and constraints (Tham, 2024; Veza *et al.*, 2022). Curriculum decisions should therefore draw on occupational task analysis and employer evidence, rather than deriving technician requirements directly from sales or registration growth.

Charging infrastructure introduces a related occupational demand that differs from vehicle servicing. Installation, commissioning and maintenance concern electrical installations and public-service reliability, while vehicle technicians work primarily on automotive systems. The Energy Commission's Guidelines on Electric Vehicle Charging System (EVCS) address installation, maintenance, competent-person requirements and licensing within their applicable scope (Energy Commission, 2025). The proposed framework, therefore, distinguishes awareness and vehicle-side charging diagnosis from the separate competence and authorization requirements for EVSE installation. Implementation in different Malaysian jurisdictions must use the rules of the relevant authority.

The Malaysian TVET landscape and EV training

Malaysian TVET is delivered across ministries and agencies, including JTM, CIAST, polytechnics, community colleges, vocational colleges, KBS institutes, MARA, GiatMARA and private providers. This institutional diversity makes coordination relevant to workforce development, but it should not be equated with poor training quality. Public reporting describes coordination through the National TVET Council and proposals for a TVET Commission (Berita Harian, 2025). The EV-TTF is a reference for collaboration within applicable agency mandates; it does not assume that proposed governance arrangements have already been implemented.

JPK's skills qualification structure includes SKM at Levels 1 to 3, DKM at Level 4 and DLKM at Level 5. Public announcements describe EV-related NOSS developed with industry participation, including vehicle service and charging-infrastructure occupations (Kosmo, 2023; RTM, 2023). These announcements establish context, but they do not substitute for analysis of the current full standards. Any program adopting EV-TTF must check the relevant NOSS codes, versions, units, and performance criteria before assigning tasks to a qualification level.

Industry partnerships illustrate different routes to building EV training capacity. Examples reported in Malaysia include Sunway's collaboration with KBS institutes (Business Today, 2024), Proton-related training with TVETMARA (The Star, 2026), and the Modenas-GiatMARA partnership for electric motorcycles (New Straits Times, 2026). These examples demonstrate activity across providers, but the announcements do not permit conclusions about actual curriculum equivalence, assessment quality or skill portability. The proposed framework offers criteria for examining those questions through program mapping and stakeholder review.

LITERATURE REVIEW

Changing competency requirements in the EV era

Electrification changes the relationship between mechanical, electrical, and diagnostic competence. Battery electric vehicles use traction batteries, battery management systems, power electronics, electric motors and charging systems that require appropriate system knowledge. EV education literature identifies battery systems, electrical diagnosis, and charging among relevant training areas (Ariwibowo *et al.*, 2026; Nursyafti *et al.*, 2026). The exact tasks and depth required vary by occupation, and a curriculum must therefore distinguish between common knowledge and specialized work rather than assume that every technician needs every advanced skill.

Three design considerations are relevant. Safety performance is a prerequisite for practical work involving hazardous energy, and the precautions must match the task and vehicle (HSE, 2025). Diagnosis also requires interpreting electrical measurements and software-generated information, thereby motivating the inclusion of system knowledge and data literacy (Ariwibowo *et al.*, 2026). Finally, the EV ecosystem includes charging installations and battery-related activities whose occupational boundaries differ from routine vehicle

maintenance (Junid *et al.*, 2024). These considerations support explicit sequencing and scope definition; they do not establish that every existing program is deficient.

Recent literature also considers the evolving digital component of EV technician preparation. Ariwibowo *et al.* (2026) examine digital skills integration and core competencies, while Arslan *et al.* (2025) Investigate training needs relevant to VR/AR materials. Bonnema *et al.* (2025)In an engineering-education setting, emphasize synthesis across technical domains. These sources inform the inclusion of system knowledge and digital diagnosis, although evidence from engineering courses or expressed training needs should not be interpreted as proof of effectiveness in technician-level HV training. A provisional framework can retain a stable safety foundation while allowing technical content to be revised as occupational tasks change.

International approaches to EV technician qualification

The United Kingdom's Institute of the Motor Industry (IMI) offers electric/hybrid vehicle qualifications with different occupational scopes. Provider descriptions distinguish awareness, routine maintenance, HV component repair and advanced diagnosis (Central College Nottingham, 2026; GTG Training, 2023; Hyve Training, 2024). The official IMI Level 4 Award includes knowledge and skills for diagnosis, testing and repair of live HV vehicle systems and provides an entry route to TechSafe recognition (Institute of the Motor Industry, 2022). These examples inform the proposed training sequencing, but qualification levels and professional-register recognition should not be treated as automatic equivalents of workplace authorization. IMI levels are also not assumed to be equivalent to Malaysian qualification levels.

In India, the Automotive Skills Development Council (ASDC) has developed occupation-based qualification packs and model curricula, such as the EV Service Assistant and EV Service Technician, that cover two-wheeler, three-wheeler, four-wheeler and commercial EVs and include on-the-job training (Automotive Skills Development Council, 2025). In Nigeria, the National Automotive Design and Development Council and the National Board for Technical Education developed National Occupational Standards (NOS) for EVs, motivated by the lack of a standardized curriculum for EV repair and maintenance (National Board for Technical Education, 2024). In Thailand, Anmanatarkul *et al.* (2025) mapped EV learning modules to occupations in the EV industry using expert input, while Poolkrajang & Papanai (2025) examined competency-based learning management for EV technology according to the TVET curriculum. Table 2 compares these approaches.

Table 2. Selected international approaches to EV technician qualification

Country	Body	Structure	Key design feature
United Kingdom	Institute of the Motor Industry (IMI)	Four levels: awareness, routine maintenance, system repair and replacement, live HV diagnosis and repair	Qualifications differentiated by EV task scope; TechSafe offers professional recognition. Workplace authorization remains a separate decision.
India	Automotive Skills Development Council (ASDC)	Occupation-based qualification packs (e.g. EV Service Assistant, EV Service Technician)	Covers 2-, 3-, 4-wheeler and commercial EVs; includes on-the-job training
Nigeria	NADDC and NBTE	National Occupational Standards for EV, modularized curriculum	Competency-based, industry-linked national standard
Thailand	Universities and vocational education bodies	Learning modules mapped to EV occupations	Skills mapping by industry experts; competency-based learning management

Malaysia	JPK and MARii (ILB)	EV-related NOSS within SKM, DKM and DLKM; historical announcements describe standards development	EV-related NOSS provide occupational standards. Detailed equivalence with proposed tiers has not been established here.

Sources: IMI (2022); GTG Training (2023); ASDC (2025); NBTE (2024); Anmanatarkul et al. (2025); Poolkrajang and Papanai (2025); RTM (2023).

The comparison suggests two useful design considerations: differentiation of training by occupational task and risk, and involvement of industry and safety expertise in the definition of competence. Because the countries differ in regulation, qualification structures and provider arrangements, the comparison is illustrative rather than an evaluation or ranking of national systems. Transferring a model to Malaysia requires explicit mapping against local standards and applicable workplace responsibilities.

International literature also offers lessons on *how* EV content is delivered, not only on how it is leveled. The E-DRIVETOUR program in Europe combined synchronous and asynchronous online lectures with teaching mobilities, Augmented Reality-based projects, and a short industrial internship to build basic EV skills for engineers (Kosmanis *et al.*, 2024). A related tertiary-level program organized EV content into four groups of technical topics and used blended teaching, many laboratory sessions, and a two-part problem-based project in which students troubleshot small-scale electric powertrains using Augmented Reality (Kosmanis *et al*., 2024). Earlier, Azcondo *et al.* (2014) showed that a course on power electronics for electric drive vehicles could be shared synchronously across three universities, with each institution managing its own registration and assessment. These cases demonstrate that blended, project-based, and shared-delivery models can stretch scarce EV expertise. In Malaysia, where EV-competent instructors and equipment are still limited, such models offer a practical way to scale training without requiring every institution to build its own full capacity.

Studies on EV training in the Malaysian TVET context

Research on EV training in Malaysian TVET remains in its early stages, and most studies are conceptual or review based. Basri *et al*. (2025) presented an argument for EV curriculum development in Malaysia based on a database analysis. Azman *et al*. (2025) assessed the curriculum readiness of Malaysian automotive TVET programs using Fullan's educational change theory and Rogers' diffusion of innovation theory across four dimensions, namely policy direction, institutional capacity, human capability, and curricular alignment. They concluded that despite the NAP 2020 and LCMB, many automotive TVET programs still emphasize ICE technologies due to inadequate infrastructure, insufficiently qualified educators, and weak industry collaboration. Qianyu *et al.* (2024) positioned TVET institutions as catalysts for sustainable EV skills development. Zehao *et al.*, (2025) applied socio-technical systems theory and identified five critical misalignments, including technical infrastructure and social capacity, policy-practice integration, industry-academia collaboration, and accreditation integration. On the educator side, a scoping review of Malaysian TVET educators' competency identified issues such as lack of technical competency, lack of practical skills training and industry experience, and the need for greening TVET (Saipudin & Suhairom, 2021).

Studies of Malaysian learners provide adjacent rather than EV-specific evidence. Wong & Abdullah, (2025) examined job readiness in electrical and electronics, while Azmi *et al.*, (2019) and Yuzainee *et al.* (2011) considered engineering preparation and employer expectations. These studies highlight technical knowledge, communication, and workplace preparation, but their findings cannot be directly generalized to EV technician performance. In the EV-TTF, communication and teamwork are proposed as observable practices, such as reporting isolation status, handing over a vehicle, and escalating tasks beyond one's competence.

The charging infrastructure side has received even less attention. Junid *et al.* (2024) compared EV charging regulatory compliance in Malaysia with that of other countries, covering licensing, registration, safety, fire protection, payment systems, and uptime, and argued that TVET plays a key role in training manpower for effective regulatory compliance; they recommended improvements to both regulations and TVET syllabi. This

is an important link because charging equipment is installed in public spaces and connected to the grid, so competence gaps can pose risks to the public, not just to technicians. It supports the decision in this paper to treat charging systems and EVSE as a distinct competency domain with its own pathway.

Theoretical Foundation: Competency-Based Training

Concept and principles of CBT

Competency-Based Training (CBT), also referred to as competency-based education and training (CBET), is an outcome-based approach in which the curriculum, delivery, and assessment are organized around competency standards that describe what a worker must be able to do in the workplace. In the Australian national training system, which has strongly influenced CBT models in Asia, competency is defined as the specification of knowledge and skill and the application of that knowledge and skill to the standard of performance expected in the workplace, and CBT is described as performance-based, standards-based and related to realistic work practices (NCVER, 2026). Hodge (2007) traced the origins of CBT to behavioral objectives and the American competency-based teacher education movement, before it became the basis of national training reforms in Australia and the United Kingdom. Smith (2010), reviewing twenty years of CBT in Australia, noted that the approach is characterized by strong adherence to industry-developed competency standards. Today, competence-based education is a prevailing trend in vocational education in countries such as Australia, the United Kingdom, the United States, Germany and the Netherlands (Sun *et al.*, 2025).

From the literature, five core principles of CBT can be identified (Chea, 2019; Deissinger & Hellwig, 2005; Mulder, 2017):

1. **Industry-defined standards.** Learning outcomes are derived from occupational standards that are developed by industry experts, commonly using job analysis methods such as DACUM.

2. **Modular and unit-based curriculum.** Content is organized into units of competency or modules that build up to a full qualification.

3. **Performance-based assessment.** Learners are assessed on their ability to perform tasks to a specified standard, typically as "competent" or "not yet competent", rather than by comparison with other learners.

4. **Flexible, learner-paced progression.** Learners progress when they demonstrate competence, not after a fixed time, and prior learning can be recognized.

5. **Workplace relevance.** Training is delivered in realistic work environments, often combining institutional and workplace learning.

CBT in the Malaysian skills system

The Malaysian skills system provides a practical setting for applying CBT principles. NOSS specifies occupational competencies, while accredited programs and assessment arrangements support SKM, DKM, and DLKM awards. The National Dual Training System (Sistem Latihan Dual Nasional, SLDN) connects institutional and workplace learning. Alignment with this system is an implementation requirement for the proposed framework, but actual adoption depends on checking current NOSS units, performance criteria and accreditation requirements. The provisional tiers below do not replace these requirements.

Malaysian studies examine occupational standards, delivery, assessment and industry experience as aspects of automotive workforce preparation (Abd Samad *et al*., 2017, 2018). Seman *et al.* (2024) discusses the HETVET@UiTM framework as an approach to connecting education with occupational and industrial expectations. These studies provide context for using a competency-oriented framework, but they do not validate EV-TTF or establish stakeholder acceptance of its particular tiers and assessment rules. Those decisions remain subject to the proposed mapping and expert review.

Critiques of CBT and their relevance to EV training

CBT has also received important critiques. Wheelahan (2007) argued that CBT tends to tie knowledge to specific workplace tasks and may deny learners access to the theoretical knowledge they need to understand and adapt to new situations. Biemans *et al.* (2004, 2009) highlighted pitfalls in implementing competence-based VET, including vague definitions of competence and the difficulty of developing valid assessments. Mulder (2017) showed that the concept of competence is interpreted differently across European countries, with the Australian and British task-based interpretation being narrower than the holistic European understanding.

These critiques are especially relevant for EV training. EV technology evolves very quickly; battery chemistries, system voltages and software architectures change from one model generation to the next. A narrow, task-based CBT that trains technicians only to follow a specific OEM procedure may produce workers who cannot transfer their skills to new platforms. At the same time, HV safety requires strict, procedure-based competence, with little room for improvisation. The framework proposed in this paper responds to this tension by combining two types of competency: (a) *procedural safety competencies*, which must be demonstrated exactly according to a standard and are suitable for strict CBT assessment, and (b) *conceptual system competencies*, such as understanding of EV architecture and electrical principles, which provide the underpinning knowledge for diagnosis and for adapting to new technology. This position is consistent with the broader view of competence by Mulder (2017) that integrates knowledge, skills and attitudes.

CBT contributes performance standards and workplace relevance; the critiques identify the need for knowledge that transfers beyond a prescribed task. IMI qualifications illustrate differentiated EV task scopes, while Malaysian readiness studies address curriculum and institutional conditions (IMI, 2022; Azman *et al*., 2025; Zehao *et al*., 2025). EV-TTF brings these perspectives into one provisional implementation model. Its distinguishing proposal is to make safety evidence a mandatory progression requirement while retaining a separate workplace authorization decision. The framework does not claim that its domains or four-tier structure are individually novel.

METHODOLOGICAL APPROACH

This study is a non-empirical conceptual model-development exercise based on an interpretive synthesis of selected sources. It adapts established CBT principles to the task-dependent risks and institutional conditions of EV training. Jaakkola, (2020) distinguishes theory synthesis, theory adaptation, typology, and model development, and emphasizes the need to explain the role of theory in conceptual research. The present contribution is a provisional model informed by theory adaptation, rather than a systematic review or an empirically validated extension of CBT.

The source set comprises the publications and public documents cited in this paper. Sources were selected for their relevance to EV tasks, competency-based vocational education, Malaysian policy and institutional delivery, or international qualification examples. This is a purposive and interpretive selection. No reproducible database search, screening count, quality score or exhaustive coverage is claimed. Scholarly studies inform educational arguments, official safety and qualification documents define occupational boundaries, and news announcements provide only contextual examples.

The revised conceptual analysis organizes the source arguments around five design questions: which occupations and standards guide provision; what knowledge and performance are needed; how prerequisites should be sequenced; how competence should be taught and demonstrated; and what institutional conditions enable implementation. CBT informs the distinction between learning outcomes and performance evidence. Its critiques inform the inclusion of system knowledge and transfer across platforms (Wheelahan, 2007; Biemans *et al*., 2004, 2009; Mulder, 2017). HV guidance informs task-dependent precautions and the separation of course completion from workplace decisions (HSE, 2025).

Framework components were then specified as design responses to these questions, and five propositions were formulated to state expected relationships and their boundary conditions. Table 5 records the principal source-to-component rationale. The analysis is interpretive, not an independently coded thematic study. A complete

mapping of current NOSS units and regulatory requirements remains a prerequisite for implementation rather than a procedure asserted to have been completed here.

The Proposed Ev Technical Training Framework (Ev-Ttf)

Overview of the framework

The EV-TTF contains five components. Policy and industry alignment (C1) identify occupational priorities. Competency domains (C2) specify the knowledge and performance to be developed. The vehicle-training pathway (C3) sequences learning by task complexity and risk. Delivery and assessment (C4) generate evidence of competence. Institutional enabling conditions (C5) determine whether the proposed learning and assessment can be implemented. The expected immediate outcome is demonstrated competence within a defined scope. A subsequent workplace decision authorizes specified tasks, subject to applicable requirements and controls. Safety and employability are longer-term outcomes to be evaluated, not outcomes demonstrated by this paper. Figure 1 summarises these relationships.

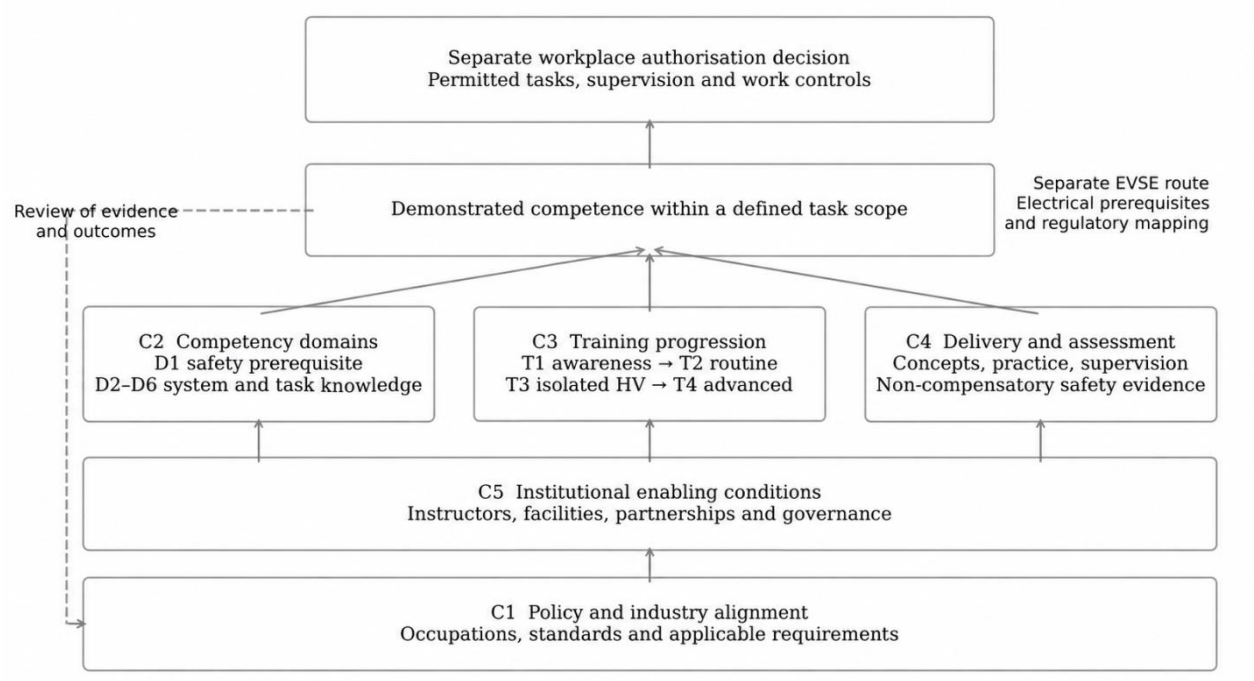


Figure 1. Proposed EV-TTF relationships between institutional conditions, learning, assessment, and task-specific workplace authorization. Arrows represent design relationships, not empirically estimated causal effects.

Component 1: Policy and industry alignment

Policy and industry alignment link training priorities to occupational demand and applicable standards. MARii, relevant industry stakeholders, and TVET providers can inform occupational profiles and identify tasks requiring curriculum updates, subject to their existing mandates. Alignment should include OEMs, independent workshops and charging-infrastructure specialists because their tasks and access to technical information differ. Any proposed coordinating mechanism must operate within the actual responsibilities of the relevant agencies; the framework does not assume that a planned institution already has the authority to regulate EV training.

Collaboration also requires explicit responsibilities. Malaysian studies discuss institutional–industry partnership constraints and models of cooperation (Subri *et al.*, 2022; Whah *et al.*, 2018), while Pisal *et al.*(2015) relates automotive talent development to industry needs and policy. In the proposed framework, a coordinating group would maintain the occupational mapping, document curriculum changes and consult relevant standards bodies. Training providers would remain responsible for delivery and assessment within their approved scope. These are implementation proposals rather than descriptions of an established EV governance arrangement.

Component 2: EV competency domains

Six provisional competency domains are proposed from the concepts discussed in the selected EV literature and qualification examples (Table 3). Domain definitions distinguish general system knowledge from tasks that require demonstrated performance. They are not presented as an exhaustive extraction of Malaysian NOSS: a unit-by-unit comparison with the current full standards is required before curriculum adoption. The framework-level source mapping in Table 5 makes the design rationale explicit.

Table 3. Proposed EV competency domains

Domain	Scope	Example competencies	Main source of evidence
D1. HV safety and risk management	Safe working around and on HV systems	Identify HV hazards; demonstrate applicable isolation and verification procedures; select task-appropriate controls; report damaged batteries and escalate unsafe conditions.	HSE (2025); IMI (2022); Nursyafti *et al*. (2026)
D2. EV architecture and electrical fundamentals	Underpinning knowledge for all other domains	Explain BEV, HEV and PHEV architecture; apply DC and AC circuit principles; use multimeters and insulation testers correctly	ASDC (2025); Azman *et al*. (2025)
D3. Traction battery and BMS	Energy storage systems	Explain battery and BMS operation; interpret diagnostic data; assess battery condition within the training scope. Module-level work requires separately demonstrated competence and applicable OEM procedures.	Nursyafti *et al*. (2026); IMI (2022)
D4. Electric drive, power electronics, and thermal management	Motor, inverter, DC-DC converter, cooling	Diagnose motor and inverter faults; test DC-DC converter; service battery and power electronics cooling circuits	Nursyafti *et al*. (2026); Sun *et al.* (2025)
D5. Charging systems and EVSE	Vehicle-side charging knowledge and a separate EVSE occupational route	Explain AC/DC charging; diagnose vehicle-side charging faults within scope. EVSE installation, commissioning, and maintenance follow a separate standard and regulatory pathway.	Energy Commission (2025); Junid *et al*. (2024)
D6. Diagnostics, software, and connectivity	Data-driven fault finding	Use scan tools and live data; diagnose vehicle network communication; perform software updates according to OEM procedure	Sun *et al*. (2025); ASDC (2025)

D1 is a mandatory progression condition for practical tasks involving HV systems. The relevant safety performance must be demonstrated before exposure to the task, rather than inferred from an overall course score. D5 has two parts: knowledge of charging and vehicle-side diagnosis within automotive training, and a separate occupational route for EVSE installation, commissioning, and maintenance. The latter requires its own standards mapping, electrical prerequisites, and applicable regulatory requirements (Energy Commission, 2025).

Communication, teamwork, and professional judgment are embedded across the six domains. Observable examples include confirming isolation status, recording diagnostic decisions, reporting damaged batteries, and escalating work outside the permitted scope. D6 covers scan tool use, data interpretation, and vehicle communication systems. Emerging digital topics may be added when supported by occupational analysis, but interest in a technology alone is insufficient to make it a mandatory competence for technicians (Ariwibowo *et al.,* 2026).

Component 3 Four-tier vehicle training pathway

The proposed vehicle-training pathway uses four tiers to distinguish awareness, routine service, de-energized HV work, and advanced diagnosis. It draws on the task differentiation illustrated by IMI qualifications, without asserting equivalence between the British qualification system and SKM, DKM, or DLKM (IMI, 2022; GTG Training, 2023). Table 4 indicates possible Malaysian program locations for expert review. These placements are curriculum suggestions; equivalence requires mapping learning outcomes, performance evidence, and qualification descriptors. They do not confer legal or workplace permission.

Table 4. Proposed vehicle training tiers and indicative Malaysian program locations

Tier	Title	Proposed task and training scope	Main domains	Indicative program location
Tier 1	EV awareness and safe handling	Recognize EVs and HV hazards; move, park, and handle EVs safely; no work on HV systems	D1 (awareness), D2 (basic)	Awareness module within relevant programs; short-course access for related workers. No qualification equivalence asserted.
Tier 2	EV routine service	Routine non-HV service after task-specific precautions; identify limits and escalate. Isolation or other controls follow the vehicle procedure.	D1, D2, D6 (basic)	Possible SKM placement subject to mapping against the relevant NOSS and program requirements.
Tier 3	HV system repair and replacement	Demonstrate applicable isolation and verification; repair or replace de-energized HV components within the defined scope. EVSE installation is excluded from the vehicle route.	D1–D4; D5 vehicle-side knowledge; relevant D6	Possible advanced SKM or DKM placement subject to outcomes and performance mapping.
Tier 4	Advanced HV diagnosis and specialist battery tasks	Advanced diagnosis; live testing only where justified and controlled. Battery repair and supervisory responsibilities require separate task-specific evidence and workplace decisions.	D1–D4 and D6 advanced; D5 vehicle-side tasks	Possible DKM or DLKM placement subject to descriptors, occupational scope, and prerequisites; not automatic HV authorization.

Note. Tier numbers indicate proposed training progression, not equivalence with IMI or MQF levels. Workplace permission, licensing, and supervision are determined separately under the applicable arrangements.

Three rules guide implementation. First, prerequisites are demonstrated competencies rather than attendance at every lower-tier course; recognition of prior learning may support alternative entry, but safety performance cannot be waived. Second, qualification completion and workplace authorization are recorded separately. The responsible workplace decision-maker should specify the permitted tasks, the vehicle or system scope, supervision, and the required controls under the applicable arrangements. Third, competence maintenance should

reflect changes in technology, work experience, and assessment evidence. A refresher course alone is not proof of continuing competence, and the paper proposes no fixed renewal interval.

Component 4: Competency-based delivery and assessment

The fourth component operationalizes the CBT principles in Section 4.1 for EV training.

Delivery progresses from conceptual knowledge to simulation, controlled practical activities, and supervised workplace tasks. Simulation can prepare learners for fault interpretation and procedural rehearsal, but it does not replace direct demonstration on appropriate equipment. Training on isolated or decommissioned components must still address stored energy and other relevant hazards. The curriculum combines transferable principles with platform-specific procedures and technical information. This permits a common educational core while recognizing that actual safe work depends on the vehicle and manufacturer (HSE, 2025).

Azid *et al.* (2024) Considers stakeholder perspectives on automotive case-based simulation, Arslan et al. (2025) examine needs for VR/AR materials, and Kosmanis *et al*. (2023, 2024) describe blended EV education. Noor *et al.* (2022) addresses interactive multimedia in TVET. Together, these studies provide a rationale for considering digital preparation, but preferences, usability, and instructional examples are not direct evidence that simulation reduces HV incidents. Its place in EV-TTF is therefore a pedagogical proposal whose transfer to practical performance must be evaluated.

Recognition of prior learning can support experienced ICE technicians without requiring repetition of competencies they can already demonstrate. Entry decisions should assess both relevant prior competence and EV-specific gaps. No applicant should receive an exemption from the required HV safety assessment solely because of the length of service or possession of an ICE qualification. Bridging modules and supervised practice should be determined by the tasks sought and documented assessment evidence.

Kasman *et al.* (2018) discusses continuing professional development and enterprise-based skill formation in Malaysian mechanical industries. This supports attention to existing workers, although it does not establish the number of ICE technicians who need EV conversion or an appropriate course duration. The proposed upskilling route should therefore be designed with workshops and training providers and evaluated against performance criteria rather than speed of completion alone.

Assessment combines practical tasks, oral questioning, and written evidence according to the competence being assessed and applicable NOSS requirements. Safety-critical performance uses a non-compensatory rule: failure on a predefined critical action results in 'not yet competent' for that assessment unit, even if other performance is strong. Critical actions and reassessment procedures must be agreed with relevant technical specialists. Advanced tasks require assessors with appropriate current competence, explicit rubrics, and moderation. Industry involvement can improve relevance, but assessor independence and consistency must be established rather than assumed. Workplace authorization follows a separate decision based on this evidence and the actual work conditions.

Component 5: Enabling conditions

Four institutional conditions support implementation. Instructors need task-relevant technical competence, teaching capability, and current access to industry procedures. Facilities need an appropriate practical-work environment, maintained equipment and controls suitable for the tasks taught. Partnerships need clearly defined responsibilities for placements, supervision and access to technical information. Governance needs assessment, moderation, incident reporting, and a documented review process. Before introducing a tier, providers should verify that these conditions match its activities. The framework proposes this review as a readiness requirement; it does not claim that all Malaysian institutions currently meet or fail it.

Abdullah *et al.* (2025) examines industry engagement strategies in Malaysian apprenticeship provision. Its findings provide reasons to consider administrative flexibility and implementation arrangements when designing EV placements. However, the relative effects of incentives and flexibility in that setting cannot be assumed to

apply to EV workshops. Providers should examine employer participation, placement quality and supervision capacity directly before selecting an engagement strategy.

Table 5. Principal evidence and design rationale for EV-TTF components

Component	Principal sources	Design rationale and boundary
C1 Alignment	Tham (2023, 2024); Subri *et al*. (2022)	Link occupational priorities and collaboration; policy intent is not evidence of implementation.
C2 Domains	Nursyafti *et al*. (2026); Ariwibowo *et al*. (2026); IMI (2022)	Identify provisional knowledge and task areas; full NOSS mapping remains necessary.
C3 Progression	IMI (2022); HSE (2025)	Differentiate task scope and risk; qualification levels do not automatically confer authorization.
C4 Assessment	Smith (2010); Biemans *et al*. (2009); HSE (2025)	Combine performance evidence with knowledge assessment; critical safety failures cannot be offset by other scores.
C5 Conditions	Azman et al. (2025); Saipudin and Suhairom (2021); Subri *et al*. (2022)	Check instructors, facilities, and partnerships; institution-level sufficiency must be assessed directly.
EVSE branch	Energy Commission (2025); Junid *et al*. (2024)	Use a separate occupational and regulatory mapping; vehicle training alone is insufficient.

DISCUSSION AND IMPLICATIONS

Theoretical implications

The conceptual contribution is a context-specific integration of CBT with task-dependent safety progression. The framework separates attainment of qualifications, demonstrated task competence, and workplace authorization. This distinction addresses a limitation of interpreting a qualification or aggregate score as sufficient evidence for all work within a technology area. It also links procedural safety to conceptual knowledge: strict performance standards govern hazardous tasks, while system understanding supports diagnosis and adaptation. These are proposed relationships rather than an empirically established extension of CBE theory. The framework's explanatory value depends on whether the propositions below improve understanding beyond existing qualification and curriculum models.

The adjacent frameworks clarify EV-TTF's scope of contribution. CIPP provides an implementation perspective, MyDigCompTVET informs educator development, and the NDT bibliometric study motivates closer connections between competence assurance and performance (Hani, *et al.*, 2026; Hani, Ismail, Fajarianto, *et al.*, 2026; Mohamad, *et al*., 2026; Mohamad, Ismail, Hani, & Khalid, 2026). EV-TTF specifies these concerns for vehicle tasks and occupational boundaries while retaining CBT as its principal training foundation. It does not merge educator competence, technician competence and institutional capacity into one construct.

Propositions for empirical examination

The following propositions are analytical expectations derived from the design rationale, not results. Training progression means permission to undertake a more demanding learning activity; workplace authorization means a separate decision permitting specified occupational tasks. Evaluation should identify the task, platform, supervision and assessment conditions rather than treating tier membership as a single outcome.

Proposition 1. When assessment standards, learner preparation and task exposure are comparable, requiring demonstrated safety-critical performance before progression is expected to reduce critical procedural errors relative to progression based only on aggregate course scores. The mechanism is the exclusion of compensatory scoring for hazardous actions. This expectation requires direct performance testing and does not imply that a course can eliminate workplace incidents.

Proposition 2. Training that combines conceptual system knowledge with platform-specific procedural practice is expected to support stronger diagnostic transfer across vehicle platforms than procedural practice alone. The mechanism is use of electrical and system principles to interpret unfamiliar configurations. Transfer remains conditional on access to the relevant manufacturer information and must not be interpreted as permission to improvise safety procedures.

Proposition 3. The relationship between structured training progression and demonstrated competence is expected to depend on instructor competence and task-appropriate facilities. The mechanism is the provider's capacity to offer valid practice, supervision and assessment. A tiered curriculum implemented without these conditions may produce completion records without comparable practical performance.

Proposition 4. Workplace authorisation decisions based on current task-specific performance evidence and a defined work scope are expected to correspond more closely to demonstrated competence than decisions based on qualification level alone. The mechanism is matching the evidence to the actual task and controls. This proposition concerns decision quality, not a change to legal powers or statutory licensing.

Proposition 5. A competence review that considers work experience, performance evidence, and changes in technology is expected to support stronger retention of safety-critical performance than reliance on initial qualification completion alone. The mechanism is the identification and correction of skill decay or procedure changes. Appropriate review intervals and criteria require empirical study and applicable professional requirements.

Practical implications

For policymakers and standards bodies, the framework offers a basis for comparing program coverage and identifying where occupational routes require clearer articulation. For providers, it supports a curriculum matrix linking domain, task, prerequisites, assessment evidence and institutional resources. For employers, it distinguishes training records from task-specific permission and supervision decisions. EVSE specialists should develop the charging-infrastructure branch in accordance with applicable electrical requirements rather than treating vehicle training as sufficient preparation. Implementation should begin with a limited set of mapped tasks and a provider readiness review, followed by a pilot that records critical errors, assessment agreement and transfer across vehicle platforms.

Equity and regional access

Advanced equipment and specialist instructors may be concentrated in particular regions, creating a potential access constraint. A regional-center model could widen access to advanced training, but it could also impose travel costs and disrupt employment. Equity should therefore be assessed through program availability, participation, completion, travel burden, and access to placements, including Sabah, Sarawak, and rural communities. Shared facilities, supported travel and modular scheduling are possible responses. Their feasibility and effects require investigation; the tiered structure alone does not guarantee equitable access.

Limitations And Future Research

The framework has not been empirically validated. Its evidence base is a selected, interpretive source set rather than an exhaustive systematic review, so omission and selection bias are possible. International examples differ in regulation and qualification structure and cannot be transferred without local mapping. The paper does not analyse every current Malaysian NOSS unit or quantify workforce demand. It primarily concerns passenger-vehicle service and repair, with a separate conceptual branch for charging infrastructure. Application to

manufacturing, electric motorcycles, buses, commercial vehicles, damaged-vehicle recovery or battery recycling requires additional occupational analysis.

Future work should first map full current standards, qualification descriptors and workplace tasks against the proposed domains and tiers. Expert review should include vehicle repair, EVSE, safety, assessment, TVET delivery, and independent workshop perspectives. Delphi or Fuzzy Delphi can assess content relevance and agreement, but consensus cannot establish practical safety effectiveness. Pilot implementation should assess direct performance, critical errors, assessor agreement, retention and transfer across platforms. Surveys may examine institutional readiness; structural equation modeling is appropriate only where constructs and relationships are clearly specified, and suitable data are available. Perception scores should not substitute for evidence of task competence or authorization. Subsequent studies can examine cost, access and applicability across sectors and ASEAN settings.

CONCLUSION

The EV transition creates a need to connect automotive workforce preparation with the risks and knowledge demands of electrical and software-based systems. The EV-TTF proposes five linked components to support that task in Malaysian TVET: policy and industry alignment, competency domains, a vehicle-training pathway, delivery and assessment, and institutional conditions. Charging-infrastructure work is treated as a related occupational route with separate requirements.

The framework's central design principle is that safety-critical performance is a mandatory condition of practical progression, supported by conceptual knowledge that enables adaptation. Qualification completion is distinguished from task-specific workplace authorization. Five propositions specify expected relationships for future testing; they are not reported as findings of training effectiveness. The contribution is a provisional integration of established principles for curriculum planning and implementation review.

Before adoption, the framework requires detailed mapping to current standards, review by relevant technical and regulatory stakeholders, and performance-based pilot evaluation. With these steps, it can provide a common reference for examining EV training quality and coordination while retaining the occupational and jurisdictional boundaries necessary for implementation.

Declarations

Ethics. This conceptual study uses published literature and public documents. It reports no participant recruitment, interviews, identifiable personal data or animal research.

Data availability. No primary dataset was generated or analysed. The sources underpinning the conceptual framework are identified in the references and the component mapping in Table 5.

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