프로젝트 전체를 **온톨로지 관점**에서 정리하면, ‘HVDC 물류 생명주기’를 하나의 **지식그래프(Ontology)** 로 모델링할 수 있습니다.  
핵심은 **“물류행위(Activity)”가 아닌 “관계(Relation)”** 중심으로 보는 것입니다 — 사람, 문서, 물품, 절차, 시스템 간의 연결망.

**🔶 1. Ontology Root Class**

**hvdc-adopt-logiontology**

| **Layer** | **Ontology Domain** | **대표 엔티티** | **관계 키(Relation)** |
| --- | --- | --- | --- |
| **L1** | Physical Flow | Material, Cargo, Port, Site, Vessel | movesFrom, movesTo, storedAt, handledBy |
| **L2** | Document Flow | BL, CI, PL, COO, eDAS, MRR, OSDR | certifies, refersTo, attachedTo |
| **L3** | Actor Flow | SCT, JDN, ALS, ADNOC, Subcon | responsibleFor, approves, reportsTo |
| **L4** | Regulatory Flow | MOIAT, FANR, Customs, DOT | requiresPermit, compliesWith, auditedBy |
| **L5** | System Flow | eDAS, SAP, NCM, LDG | feedsDataTo, validates, monitoredBy |

**🔶 2. Core Classes (from Workshop)**

| **Class** | **Subclass of** | **Description** | **Onto-ID** |
| --- | --- | --- | --- |
| **Material** | Asset | 자재 및 기자재(Transformer, Cable, CCU 등) | hvdc-asset-mat |
| **TransportEvent** | Activity | Inland, Marine, Offloading, SiteReceiving | hvdc-act-trans |
| **Storage** | Location | Yard, Warehouse, Laydown | hvdc-loc-stor |
| **Inspection** | Process | MRR, MRI, OSDR | hvdc-proc-insp |
| **Permit** | Document | PTW, Hot Work, FRA | hvdc-doc-perm |
| **Actor** | Agent | SCT, ADNOC L&S, Vendor | hvdc-agent-role |
| **PortOperation** | Activity | RORO/LOLO, Sea Fastening | hvdc-act-port |

**🔶 3. Relation Model (Partial)**

Material --hasDocument--> MRR

Material --transportedBy--> TransportEvent

TransportEvent --operatedAt--> Port

TransportEvent --requires--> Permit

Permit --approvedBy--> ADNOC

Storage --monitoredBy--> SCT

Inspection --reportedAs--> OSDR

Actor(SCT) --usesSystem--> eDAS

이 관계망은 logiontology.mapping 모듈에서 RDF triple로 구현 가능:

:TR001 rdf:type :Transformer ;

:hasDocument :MRR\_20240611 ;

:storedAt :Mussafah\_Yard ;

:handledBy :SCT ;

:requiresPermit :FRA\_202405 ;

:transportedBy :LCT\_Operation\_202405 .

**🔶 4. Lifecycle Ontology (Material Handling Flow)**

**Stage 1 – Importation**  
→ hasDocument(BL, CI, COO) → customsClearedBy(ADOPT) → storedAt(PortYard)

**Stage 2 – Inland/Marine Transport**  
→ transportedBy(LCT/SPMT) → requiresPermit(DOT/FRA) → monitoredBy(ALS)

**Stage 3 – Site Receiving**  
→ inspectedBy(QAQC) → resultsIn(MRR/OSDR) → issuedAs(MIS)

**Stage 4 – Preservation & Foundation**  
→ preservedBy(HitachiStd) → foundationBy(Mammoet) → approvedBy(OE)

**🔶 5. Alignment with AI-Logi-Guide**

| **Ontology Node** | **대응 모듈** | **기능적 의미** |
| --- | --- | --- |
| Activity | pipeline | 단계별 절차 정의 |
| Document | rdfio, validation | eDAS·MRR 등 문서형 triple |
| Agent | core | 역할/권한 모델 |
| Location | mapping | Port/Site 좌표·거점 |
| RiskEvent | reasoning | Weather-Tie·Delay inference |
| Report | report | KPI/Inspection 리포트 |

**🔶 6. Semantic KPI Layer (Onto-KPI)**

| **KPI Class** | **Onto Property** | **계산식** | **Source** |
| --- | --- | --- | --- |
| **On-Time Delivery** | meetsETA | ETA vs Actual ≤12% | ETA MAPE Rule |
| **Inspection Compliance** | hasMRR | MRR Count / Total Deliveries | QC Gate |
| **Storage Efficiency** | occupies | Used m² / Available m² | WH Forecast |
| **Safety Conformance** | requiresPermit | Valid PTW/FRA % | HSE Docs |

**🔶 7. Ontological Integration View**

[Material]

⟶ [Document: CI/PL/COO/eDAS]

⟶ [TransportEvent: LCT/SPMT]

⟶ [Location: Port → Yard → Site]

⟶ [Inspection: MRR/OSDR]

⟶ [Report: KPI/Dashboard]

⟶ [Governance: AI-Logi-Guide Rules]

이 전체를 hvdc-adopt-ontology.ttl로 export하면,  
GitHub macho715/ontology-insight에서 RDF 시각화 및 reasoning 연결 가능.

**🔶 8. 요약 메타 구조**

{

"Ontology":"hvdc-adopt-logiontology",

"CoreClasses":["Material","TransportEvent","Storage","Inspection","Permit","Actor","PortOperation"],

"PrimaryRelations":["hasDocument","transportedBy","storedAt","requiresPermit","inspectedBy","approvedBy"],

"AlignmentModule":"AI-Logi-Guide v2.1+",

"ExportFormat":["RDF/XML","TTL","JSON-LD"]

}

이 프레임이면, HVDC 프로젝트 전체가 **“문서-행위-공간-주체-규정”의 지식망**으로 정규화됩니다.  
다음 단계는 logiontology.reasoning 모듈에서 **Rule-based inference** 정의 — 예컨대 “운송허가가 누락된 자재는 SiteReceiving 단계로 진행 불가” 같은 정책을 OWL constraint로 명세하면 완성됩니다.