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The study of project cargo logistics operation: a general overview

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Abstract

The recent renewable energy infrastructure development trend and modular construction concept surge academic interest in the project logistics sector. The project logistics is the transportation processes for oversized cargo, critical and high value, that belong to infrastructures projects; that require specialised stowage, lifting and transporting loaded and discharged at different ports. This study aims to introduce project logistics to the public sector. The author uses the descriptive review to elaborate on the niche problem of project cargo transportation. The flow of project cargo operation from the fabrication yard to the final installation site is discussed in this paper. Planning of project cargo logistics requires an integrated planning approach that considers the following aspects total delivery cost management, end-to-end visibility, transport routing management, variability management, integrated international and domestic workflow, and technical safety consideration. The decision-making for fleet selection should be based on the optimum scenario evaluating the damage's total logistics cost, delivery time, risks and consequences. This study can be a guide to accommodate multidiscipline studies that consider commercial, technical, and safety aspects of project logistics.

Keywords: Project logistics, Port infrastructure, Heavy lifting, Heavy haulage, Out of gauge

Introduction

The movement of large and heavy cargo for construction projects is part of tramp shipping, which is still considered a niche problem (Pache 2019). At the same time, containerisation has dominated international trading in intermodal transport, with 20' or 40' steel boxes transported with different modes of transport from vessels, trains, and trucks and handled in many other ports across the world throughout the end-to-end supply chain (Song 2021). The recent research was more focused towards containerisation and bulk shipping. Currently, the research in the shipping industry mainly concentrates on bulk and containerisation shipping. Not many academia study the logistics system for oversized or Out of Gauge (OoG) cargoes, which exceed the dimensions of 40ft High Cube containers size.

The recent expansion of infrastructure development towards the modularisation and renewable energy sectors surges academic interest in the project logistics sector. Project logistics is the transportation processes for cargo with characteristics such as large, heavy, out-of-gauge, high-value, and critical items. The project cargo is usually part of an infrastructures project; that requires specialised stowage, lifting, transporting, loading, and discharging at different ports ((Pi and Club. Carefully to Carry. 2018; Denktaş Şakar et al. 2018)). The author's objective is to provide a general overview of the project logistics by consolidating the published papers discussing the related project cargo transportation.

Denktaş Şakar et al.'s study aims to find the critical enabler of value-added creation for project logistics in Turkey. The study also emphasises the lack of research in project logistics. It suggests providing value-added design to improve the critical aspects of operational efficiency and service effectiveness of the project logistics (Denktaş Şakar et al. 2018).

Malaksiano et al. proposed to evaluate the performance of non-specialised vessels carrying project cargo using the Time Charter Equivalent (TCE) as a standard performance measure of ship operating efficiency to the market rate (Malaksiano and Melnyk 2020). Comparing TCE with the FRTC (Freight Rate Time Charter) shows many opportunities for the non-specialised dry cargo vessel to perform project cargo transportation. The efficiency of project cargo transportation is influenced by the following factors: (1) the hatches' dimensions and design, (2) the size and shape of holds, (3) deck equipment, (4) the ship's cargo gears, (5) maximum permissible load, (6) manoeuvrability, and ship's seaworthiness (Malaksiano and Melnyk 2020). Based on the above characteristic, Melnyk et al. propose a methodology for decision-making for fleet acquisition based on cargo flow structure and simulating operational speed at optimal speed or slow steaming option (Melnyk and Malaksiano 2020).

Melnyk et al. discuss the optimisation model for the delivery of project cargo in terms of transport cost, delivery time, and probability of damage. In this study, the optimisation model for the delivery of project cargo uses weightage priority between delivery time, transport cost, and cargo safety. The study suggests multimodal or combined transportation to accelerate the project cargo delivery processes (Melnyk 2020). Cargo safety is measured by identifying the potential adverse risk that might occur during the project cargo's transportation and loading/unloading and estimating the consequences of such adverse events to a vessel or the load itself. Onyschchenko et al. propose the probabilistic assessment model on the occurrence of random negative events and their related consequences that can be used to make decisions to select fleet, port, and transportation routes (Onyshchenko et al. 2021).

The interest in the project cargo logistics promotes the research for the safe transport of oversized cargoes within the city's land transport infrastructure. Petru et al. discuss determining the parameters for safely passing oversized cargo on the road. This study provides the evaluation and statistical analysis of oversized cargo travelling the road in the cities of the Czech Republic. The parameter road infrastructure such as intersections radius, width, and heights for the transport cargoes and the trailer's clearance from the solid obstacles (Petru and Krivda 2021). This finding is supported by the study on the complexity of oversized cargo transportation in road transport in Polland conducted by Maxioszek. Special consideration is applied to regulate oversized cargo in the carriage's road transport, railway, and inland waterway systems (Macioszek 2019). The

Multi-criteria analysis (MCA) using the Analytical Hierarchy Process (AHP) method has been proposed by Wolnowska et al. to evaluate the transport route variants for transporting heavyweight and oversized cargo through Szczecin, Poland. This quantitative analysis method selects the best route to mobilise heavyweight loads with the lowest impact on the community and transport infrastructure along the transport path (Wolnowska and Konicki 2018).

Oktaviani et al. studied the multimodal transport model for project logistics cargo to minimise the project cargo system's transport cost and delivery time. The simulation of alternative land and marine transport to obtain the minimum transport cost to deliver railway carriage products from Indonesia to Bangladesh (Turbaningsih et al. 2022). This study suggested the multimodal transport strategy to improve the existing process to increase the competitive advantage of the manufacturing company.

The previous studies mainly discuss optimising vessel selection and route consideration. The author found a gap in that it is necessary to provide a general overview of project cargo logistics from the freight generation stage to the cargo handling at the port. More research in project cargo is necessary because it will be able to support efficient construction logistics in the future, especially for developing renewable energy infrastructure in the future.

This study focuses on the critical technical aspects of handling project cargo, the integration risk for all stakeholders involved in the project cargo supply chain, and the proposal for calculating the total project logistics cost and delivery time for each alternative transport mode. This study uses descriptive review to elaborate on the general overview of the project logistics operations. The remainder of the article is organised as follows. Section 2 will discuss the project cargo freight, Sect. 3 will discuss the project cargo modal transport, Sect. 4 will discuss the port infrastructure and potential port business and activities, and Sect. 5 will describe the project logistics operation. Finally, Sect. 6 will discuss the conclusion and future studies.

Project logistics freight

Project logistics is a fragmented market and relatively highly competitive among the niche market player. The demand for project cargo is mainly influenced by the development of industries that fall into convergent assembly manufacturing processes. The project cargo belongs to the concurrent assembly supply chain category. This type of supply chain has limited product differentiation, is fully developed in the early stage, and potentially has a lifecycle for years or decades (Vrijhoef 2011). These project cargoes mostly come from the following industries Table 1.

The Paris Agreement became a turning point for countries to set their commitment to deal with an environmental issue related to the rapid growth of the clean energy movement with LNG as transition energy and renewable energy infrastructure development such as wind, solar, and hydrogen derivatives (Turbaningsih and Mutaharah 2022). With the rise of decarbonisation concerns, developing countries urge the switch from oil and coal to LNG as the primary energy source because LNG is considered clean energy and the fastest solution with mature technology to contribute to climate change action and a sustainable environment (Turbaningsih et al. 2022). Figure 1 shows the trend of global offshore wind to 2026, it shows that the

Table 1 Project cargo categories: outbound products

Industry type (Pi and Club. Carefully to Carry. 2018)	Products	Positive factor for demand
Petroleum Industries	MODU, jack-up rig, topside & jacket for offshore platform	New gas field discovery Rig construction
	Modular structures, bullet tanks, diesel generator	Refinery plant construction
Shipbuilding	Floating structure modules	Decarbonisation policy
Renewable energy	Nachele, Wind Blade, Windmill Propeller Hydrogen/Ammonia/Methanol Infra-structure	Renewable energy infrastructure development
Power/electricity	Turbine, Generators,	Cleaner energy demand
Port industries	STS/RTMG/MHC cranes and other port equipment	Development of smart and green port industries
Railroad industries	Railway Carriage, Passenger	Sustainable infrastructure
Civil construction	Modular buildings, Excavators, Cranes, Front Loaders, Bridge Beam, Industrial Equipment	Digitalisation and automatisation

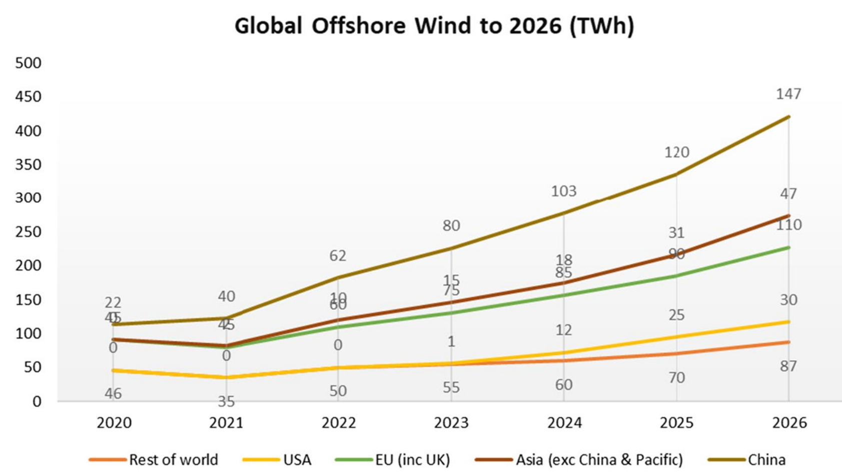

Fig. 1 The forecast of global offshore wind to 2026 (Drewry. 2022)

rising awareness of climate change impacts multiplied the demand for sustainable infrastructure, and renewable energy infrastructure development influenced the need for more advanced construction technology. Drewry 2022 predicted that the demand for onshore wind projects will grow at a CAGR of 6.1% and 25%, respectively, by 2026 (Drewry. 2022). The global hydrogen demand will increase by 5% in 2021, increasing the need for hydrogen infrastructure development worldwide (IEA. Global Hydrogen Review 2022).

Apart from the renewable energy growth, the demand for sustainable infrastructure urges the development of efficient and environmentally friendly construction technology. The traditional construction method might no longer be sufficient to meet the sustainable infrastructure concept. Modularisation offers a solution to the inflexibility of a conventional way. The modular construction concept potentially reduces the construction cost by 40% and allows parallel activities between site preparation and

Table 2 SWOT analysis for modular construction concept (Company and Modular construction: From projects to products [Internet]. 2019)

Strength	Weakness
Reduce overall construction cost & duration Reduction of construction waste Promoting sustainability concept Offering interchangeability concept	Increasing design complexity Profitable only if it meets the Economics of scale Complex transportation issue Complex project management
Opportunity	**Threat**
Cost-saving by minimising reworks Optimisation of financing cost Quality standardisation	A limited supply of specialised skilled labour Government policies Quality Perception

modular prefabrication (Kamali and Hewage 2016). Table 2 shows the SWOT analysis for the modular construction concept.

The transition to modular (offsite) construction methods opens a new market, especially for developing countries that can provide low labour costs and abundant land for prefabrication areas. Regarding the prefabrication method that supports sustainable infrastructure development, it is possible to provide efficiency in material savings of about 60% of steel, 56% of concrete, and 77% of formwork on site compared to a similar scale using conventional construction method (on-site) (Jiang et al. 2019). Unfortunately, the modular prefabrication concept still faces drawbacks, such as the economics of scale and complexity of modular transportation, since its dimension is out of gauge and exceeds ISO container size. This offsite construction model enhances opportunities for international trading within geographical regions depending on the countries' competitive advantages. The growth of international free trade offers wider business opportunities and potential for new trading connections (Lai et al. 2019). The international and regional trade increases the EPC overseas trading. The decision-making for the overseas EPC using the modular construction method affects the development of project cargo movement—the total investment for the project logistics considering the total domestic logistics costs. The domestic logistics cost consists of domestics manufacture costs (fabrication, ready-mix concrete, bulk materials, rebar and steel materials) and the overseas logistics costs (vessel charter rate, bunker pricing, currency exchange, distance, volumetric sizing, insurance and customs clearance) (Subiyanto and Totok 2020).

The supply chain in the construction industry is considered quite complex, especially for large projects. The complexity has varied depending on the site locations, raw materials and critical component origin, and construction equipment mobilisations (Jones 2005). The inbound and outbound movement for project cargo sectors significantly impacts shipping and trading. The demand for project cargo should be supported by the supply of steel products as the raw materials for fabricating modular structure products. Table 3 shows the global movement of steel products, which is the primary input for fabrication companies. China has been the major exporter and importer for the past five years, the average export declined by -4.52%, and imports grew by about 25.45% (Drewry. 2022).

Table 3 The global movement of steel products (Drewry. 2022)

Major steel exporters (000 tonnes)					
Country	**2018**	**2019**	**2020**	**2021**	**2022**
China	57,952	52,339	43,543	56,851	44,269
Japan	33,603	31,067	29,558	32,579	30,610
South Korea	27,855	28,154	26,967	25,236	24,607
Russia	26,002	22,736	21,531	24,324	23,040
Turkey	17,774	17,930	16,549	19,933	17,286
Brazil	13,373	12,506	10,605	10,989	13,609
Germany	11,576	10,870	9,632	10,598	11,052
Major steel importers (000 tonnes)					
Country	**2018**	**2019**	**2020**	**2021**	**2022**
China	16,562	20,442	43,463	35,476	29,853
United States	21,462	18,135	14,124	20,585	29,853
Turkey	13,908	12,069	12,445	15,386	29,853
South Korea	16,114	16,913	12,292	15,250	14,975
Vietnam	13,657	14,717	12,292	12,934	11,053
Indonesia	13,657	14,826	10,950	11,855	12,433

As discussed above, the project freight is highly influenced by construction sector development. The port, shipping, and logistics stakeholders should reactively respond to the global trade movement by monitoring the global demand, upgrading transportation efficiency, and adapting to future uncertainties in demand and opportunities (Lai et al. 2019) to compete in the project freight market.

Project cargo modal transport

General overview

The project cargo transportation is considered relatively expensive due to its oversized parcel. The project cargo transportation under the tramp shipping scheme does not follow a particular published schedule, which runs like a taxicab that tenders its cargo (Noshokaty 2017). The cargo handling method for project freight includes Lo-lo (Lift on, Lift off), Ro-Ro (Roll On, Roll off), or float on/off. The lifting operation of project cargo is categorised as a non-routine lift (single lift or tandem lifting). There is some alternative for marine transportation fleet for heavy cargo transportation, such as Tween Deckers, General Cargo Ships, Breakbulk Carriers, Multi-purpose Vessels, Module Carriers, Semisubmersible Heavy Lift Vessels, Barges (and tow tugs or pushers) (Pi and Club. Carefully to Carry. 2018). Offshore construction vessels such as derrick barges, pipelay vessels and dive support vessels are considered fleets for project cargo operation—their function for support the installation/removal of platforms, pipelines, risers, and other subsea equipment (Kaiser 2015). The transport planner should review the critical parameter and their relevant consideration factors (refer to Table 4).

The total cost for marine transportation operations consists of capital cost (CC), operational cost (OC), voyage cost (VC), and cargo handling cost (CHC) ((Wijnolst and Wergeland 2009; Stopford 2013)).

Table 4 Marine transportation consideration factors (Author's compilation)

Parameter	Consideration factors
Cargo properties	Cargo Weight, dimension, and CoG location, Cargo supporting location and packaging Cargo footprint area and cargo sensitivity
Port information	Availability of services for special handling project cargo Port draft limitation (tidal window for sufficient clearance) Benign areas or open seas port
Marine Transport Route GL Noble Denton 2015a; GL Noble Denton 2016; PIANC Secrétariat Général 2014; Bechtel 2002)	Minimum navigable depth within the route Limitation size in the coastal waterways or river Potential obstruction (vertical and horizontal) Safety and security risks along the route, such as piracy and pilferage risks Marine traffic condition Environmental condition along transport route (wind speed, wave height, current speed)
Fleet information Flag State and Classification Society Rules	General Arrangement Drawing, Vessel stability booklet Liner or Tramper Alternatives Cargo handling availability and capacity
Vessel Planning Cargo Securing Manual (CSM) CSS Code (IMO Code of Safe Practice for Cargo Stowage and Securing, 2003; Resolution A.714 CTU Packing Guidelines, 2014	Cargo handling and discharging method Cargo footprint on the vessel (broken stowage) Longitudinal deck strength check Fastening requirement (welding or soft lashing) Load spreading requirement Vessel stability during sailing and berthing at the port
Operational risk	Technical risk, Equipment failure, Communication breakdown, Human error risk, commercial risk, and any other risks identified to generate a contingency plan

$$TC = CC + OC + VC + CHC \tag{1}$$

$$OC = M + MN + ST + I + A \tag{2}$$

$$VC = B + PC + CD + BS \tag{3}$$

$$CHC = LD + TL + CL \tag{4}$$

$$CC = Px\frac{1 - (1 + r)^{-n}}{r} \tag{5}$$

where: $C =$ capital cost (the current vessel value with additional 2% of inflation rate)

$M=$ manning cost

MN $=$ maintenance and repair cost

$I=$ insurance

$A=$ management overhead and administration

$B=$ bunker charges

PC= port charges

CD= Canal Dues

BS= penalty cost caused by broken stowage

LD= cargo loading and discharging cranage, cargo lifting & securing charges, stevedoring charges

TL= land transport charges from the fabrication area to the port of loading (TL)

CL= cargo claim charges (CL) if any claim arises)

P= the instalment payment

r = interest rate per period (%)

n= number of periods (years)

The heavy haulage cost involves fixed costs and variable costs. The fixed cost component is vehicle purchase or lease, insurance, registration fee, and vehicle taxes. The variable costs include vehicle repair and maintenance, fuel, fuel taxes, oil, and paid parking and tolls (VTPI 2017). The unit price for land transport cost is shown in the following equation:

$$\mathrm{LR} = \mathrm{EC} + \mathrm{LC} + \mathrm{VC} \tag{6}$$

where:

EC = equipment cost (rental charges)

LC = labour cost (mechanics, driver, operators, lashing team)

VC= variable cost (fuel cost, lashing materials, maintenance and repair charges, permit fee, and escorting charges

The long-haul distance transport made the intermodal/multimodal transport more preferable significantly when the handling cost increased, total transport distance increased, pre and post-haulage costs increased, marginal cost increased, and the resting cost for the truck drivers (Hanssen et al. 2012).

Total logistics costs

The general transportation cost consists of internal costs and external costs. The formulas to calculate the internal cost for delivery cargo from location i to location j such as follows:

$$C_{TOTinter(i-j)} = C_{Totinv-ij}+C_{LToP-i}+C_{dwlOP}+C_{CHoP}+C_{FR}+C_{BAF}+C_{CHdP}+C_{dwldP}+C_{LTdP-j} \tag{7}$$

The total internal cost consists of the total inventory cost $(C_{Totinv-ij})(C_{LToP-i})$, the prehaulage cost, post haulage cost(C_{LTdP-j}), cargo handling cost at origin (C_{CHoP}) and destination port(C_{CHdP}), dwelling time cost at the origin port (C_{dwlOP}) and destination port(C_{dwldP}), freight cost $(C_{FR})A$ nd bunkering adjustment factors(C_{BAF}). (C_{BAF}) is related to the increase in fuel cost or the need for the changing fuel type. Adding external costs to the total logistics cost contributes to green shipping. The enforcement of the IMO Sulphur Cap for international shipments makes it necessary to consider the externalities in the total logistics cost. The externalities counted included air pollution, climate change, noise, accidents and congestion (Santos and Soares 2020).

$$C_{EXT(i-j)} = Q_t \mathrm{D}_{\mathrm{P(non-ECA)}}.C_{\mathrm{P(non-ECA)}}+Q_t \mathrm{D}_{\mathrm{P(ECA)}}.C_{\mathrm{P(ECA)}}+Q_t \mathrm{D}_{\mathrm{P(inPdes)}}.C_{\mathrm{P(inPdes)}} \tag{8}$$

The total external cost $(C_{EXT(i-j)})$ is counted for delivery of a total cargo quantity (Q_t) travel outside the ECA (Emission Control Area), within ECA, and in the vicinity of the destination port. The marginal cost coefficient for each area represent in $C_{\mathrm{P(non-ECA)}}$, $C_{\mathrm{P(ECA)}}$, $C_{\mathrm{P(inPdes)}}$. The marginal cost-efficient is the total value per 1000 km corresponding to each location's environmental impacts and congestion components. The total logistics cost $C_{TOT(i-j)}$ Is the total internal cost $C_{TOTinter(i-j)}$ and external cost $C_{EXT(i-j)}$ To transport project cargo from location i to location j.

$$C_{TOT(i-j)} = C_{TOTinter(i-j)} + C_{EXT(i-j)} \tag{9}$$

The selection of transport modes objective is to obtain the minimum total logistics cost $C_{TOT(i-j)}$ while ensuring that the total delivery time ($\mathrm{T_{TOT(i-j)}}$) within the set project schedule.

Project cargo delivery time

The specific delivery schedule of cargo related to the infrastructure project significantly impacts project delay risks. Therefore, before selecting the transport scheme, it is necessary to calculate the total delivery time based on several combination transport alternatives. The total time is taken to deliver project cargo from location i to location j calculated as follows:

$$T_{TOT(i-j)} = T_{LToP-i} + T_{dwloP} + T_{CHoP} + T_{NAV} + T_{CHdP} + T_{dwldP} + T_{LTdP-j} \tag{10}$$

The component to calculate the total time taken to transport cargo from location i to location j ($\mathrm{T_{TOT(i-j)}}$) is the combination of total land transport time from the origin position to the port – i($\mathrm{T_{LToP-i}}$); total land transport time from port-j to destination ($\mathrm{T_{LTdP-j}}$); ($\mathrm{T_{dwloP}}$), ($\mathrm{T_{dwldP}}$) total dwelling time at the origin port and destination port, respectively; $\mathrm{T_{CHoP}}$, $\mathrm{T_{CHdP}}$ total cargo handling time at the origin port and destination port, respectively; and ($\mathrm{T_{NAV}}$) total navigation time.

$$\mathrm{T_{NAV}} = \frac{\mathrm{D_{P(non-ECA)}}}{\mathrm{S_{ship}}} + \frac{\mathrm{D_{P(ECA)}}}{\mathrm{S_{ship}}} + \frac{\mathrm{D_{P(inPdes)}}}{\mathrm{S_{port}}} \tag{11}$$

The navigation time calculated based on the duration requires travel outside the ECA (Emission Control Area), travel within ECA, and travel within the vicinity of the destination port (taking maximum port approaching a speed $\mathrm{S_{port}}$).

Optimal scheme for project cargo operation

The proposed method by Melynk et al. will be able to determine the optimum alternative for the delivery of project cargo in terms of the total cost, delivery time, and the probability of damage. The scenario selection should meet the minimum criteria for each alternative (Melnyk 2020).

$$C_{TOT}, T_{TOT}, S_D \underset{Si}{\rightarrow} min \tag{12}$$

The determination of each weightage criterion defines by putting coefficient factors: $\alpha_C, \alpha_T, \alpha_S$ For the cost, time, and safety criteria, respectively. The decision maker defines the weightage criteria depending on the priority level and the project's complexity. The one criterion optimisation for this case is:

$\alpha_C + \alpha_T + \alpha_S = 1$(13)

$$F(S_i) = \alpha_C \frac{C_i^{TOT} - C_{min}^{TOT}}{C_{max}^{TOT} - C_{min}^{TOT}} + \alpha_t \frac{T_i^{TOT} - T_{min}^{TOT}}{T_{max}^{TOT} - T_{min}^{TOT}} + \alpha_s \frac{S_I - S_{min}}{S_{max} - S_{min}} \underset{Si}{\rightarrow} min \quad (14)$$

where:

C_i^{TOT} = total cost for scenario (i) for cargo transportation.

C_{max}^{TOT} = maximum total cost for the various scheme for cargo transportation.

C_{min}^{TOT}= minimum total cost for the various scheme for cargo transportation.

T_i^{TOT} = total delivery time for scenario (i) for cargo transportation.

T_{max}^{TOT} = maximum expected delivery time for the various scheme for cargo transportation.

T_{min}^{TOT}= minimum expected delivery time for the various scheme for cargo transportation.

S_I = probability of cargo damage for scenario (i) for cargo transportation.

S_{max} = maximum probability of cargo damage for the various scheme for cargo transportation.

S_{min}= minimum probability of cargo damage for the various scheme for cargo transportation.

α_C = weightage factor for cargo transport.

α_T = weightage factor for delivery time.

α_S = weightage factor for safety factor for damage.

The optimal scenario for the project cargo scenario depends on what will be the most priority between cost, time, and lowest probability of damage. The probability of damage will have higher coefficients if the cargo is considered high-value and critical.

Port infrastructure for project cargo operation

The Project Cargo is a unit load package requiring special care and specific handling requirements. Special handling requirements depend on the cargo sizes and its centre of gravity (CoG), lifting points (padeye), cargo footprint and support, distribution load per (for checking of exerted load pressure), availability of cargo handling equipment and installation requirement at the final site.

The transportation route examination is mandatory for safely handling the project cargo; The project cargo dimensions might exceed the permissible load on railway bridges and overpasses, potentially obstructing the trees and other buildings. Selecting waterfront infrastructure to handle project cargo should be driven by its proximity to the construction site. Minimising the land transport distance and maximising the usage of waterway transport should be an objective for this handling. A project cargo delivery often requires inland waterways (Melnyk 2019); thus sometimes requires transfer to the cargo barges. The double-handling operation at the transhipment hubs is initiated by poor nautical accessibility of the initial port or limited infrastructures, which requires the hub and spokes transport function (Notteboom et al. 2021).

The primary driver for selecting the port's location is to achieve the minimum transport cost, which is subject to vessel fleets and suppliers. Distances and accessibility from the waterfront infrastructure to the construction site or final location of the project cargoes are the primary determinants for selecting the suitable project logistics terminal. Figure 2 shows the process for handling project logistics cargo from the fabrication site

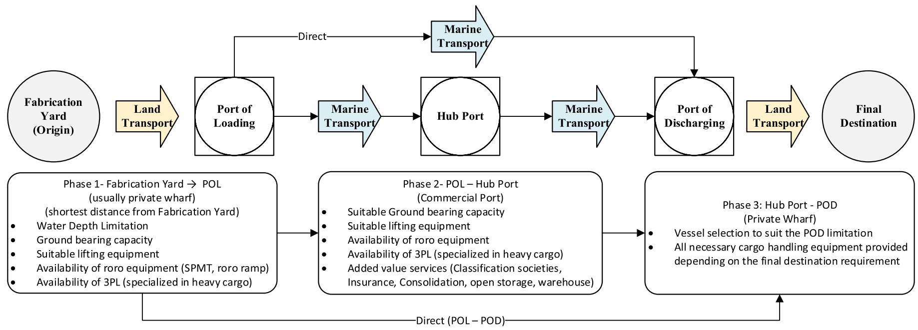

Fig. 2 Project Cargo logistics flows (Authors' illustration)

or cargo origin to the final location based on an observational study on-site. The technical aspects influenced the decision for the land transport, marine transport or vessel selection and cargo handling processes at the port.

Predicting demand for estimating the project movement is required to decide where to have regular project logistic operations. A few alternatives exist to project logistics operations by occupying the (1) multi-purpose port, shore base, shipyard or private wharf.

A multi-purpose port is a complex infrastructure, equipment and services that offer a combined and flexible response to the servicing demand of certain vessels and cargo permitting the optimum utilisation of workforce and equipment (UNCTAD 1991). The multi-purpose terminal offers flexibility to accommodate various cargo types with open storage yards. This type of terminal will suit the spot market for project cargo, short-term projects, and offshore mobilisation projects for relatively short periods (about 1 to 3 months). The multi-purpose port offers a one-stop solution such as stevedores, welding contractors, heavy-duty cranes, multi-axle trailers, port services (freshwater, bunkering), storage, cargo consolidation, minor repair and reworks, and crew change. The drawback of the multi-purpose port is that it will incur high port charges for long-term usage only for the docking charges. The tariff will follow the regular tariff rates at the port.

Shore bases are the intermodal transfer centres where the supply is assembled and collected from the onshore logistics network and transported offshore via supply vessels. The construction centres are a secondary position for offshore infrastructure and vessel fabrication; equipment and supplies are manufactured and warehoused before shipment (Kaiser 2015). The shore base can be public or privately owned. The primary purpose is usually to facilitate the movement of cargo destined for offshore operations. The shore base offers services for storage for the project cargo and is already equipped with stevedores and cranes as required by the shore base tenant. The common practice of using shore base is based on an agreed tariff per a long-term agreement between the tenant and shore base operators. The tariff rate might come monthly or as per revenue tonnage.

The private wharf and shipyard are financed mainly by private capital and owned by a single entity to serve their purpose. The fabricator's company, with a waterfront area, has a higher competitive advantage to reduce the complexity of the public ports

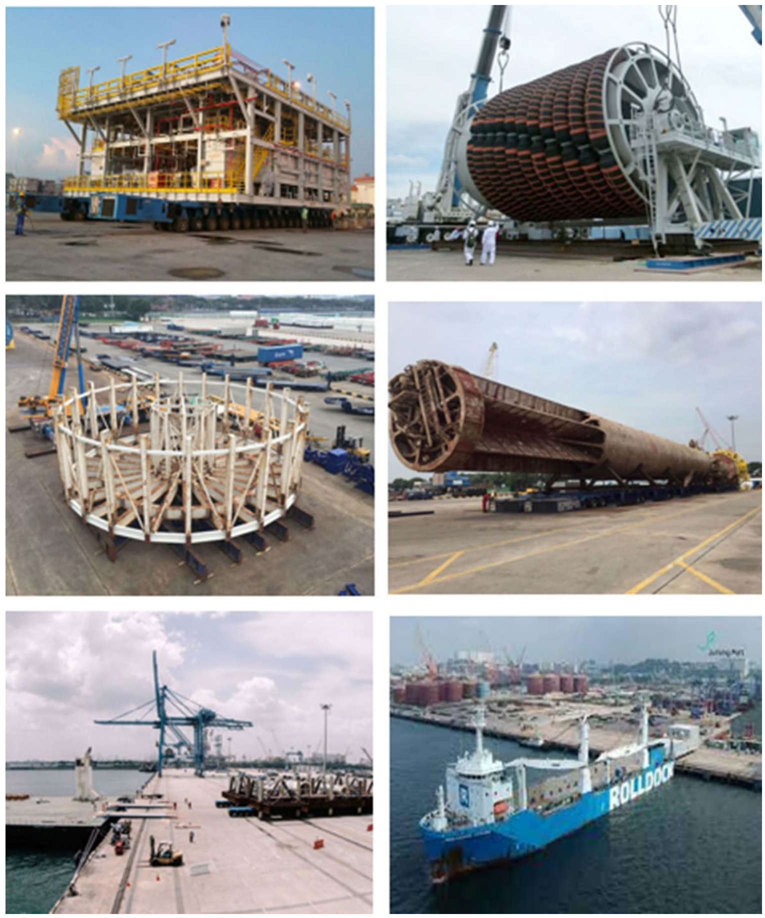

Fig. 3 Project Cargo operation at the port (Port 2022)

and minimise the port-related charges except for the cargo handling charges. The private wharf entity might hire competent stevedores and project cargo contractors to handle their cargo for their wharf. The cargo owners are not subjected to port charges because the transport and installation are usually included in the lumpsum package for the projects. Figure 3 below shows the logistic project operation at the port.

The project logistics handling operation is considered a weather-restricted process. Each port has its environmental operating limit. The operational criteria are the limiting met-ocean criteria: wave height, wind speed, and current (GL Noble Denton 2015b). The marine port activities, which include berthing, mooring, and cargo handling, must perform as per the guidance by Classification Societies that the cargo marine insurance requires. Table 5 shows the ship services and consideration factors during project cargo operation.

The weightage of the safety factor for the transport project cargo is higher than general cargo because it is a critical item for the project's construction. The following parameter should be considered to generate a heavy haulage scenario. (Table 6).

Table 5 Planning project cargo operation

#	Services	Consideration factor
1	Berthing operation	The vessel master should obtain information such as water depth, current vessel draft, wave height, current speed, wind speed and direction, vessel approach velocity, and general condition of the berth Pilotage guidance is crucial during the manoeuvring process for vessels carrying project cargo Monitoring port environmental operating limit When entering the port entrance and using pilotage and tugs services, the minimum safe ship speed is required to counteract possible current and tidal impact during the approaching process Berthing position depending on the cargo handling method: alongside wharf (Lo-lo) and Mediterranean mooring (Ro-Ro)
2	Mooring operation (Flory et al. 1998; Turbaningsih 2014)	The mooring arrangement should be as symmetrical as possible to the ship CL (centerline); the breast line should be as perpendicular as possible to the ship CL, and the spring line should be as parallel as possible with the ship's centerline The following input for mooring arrangement for barges such as environmental data (wind and current velocity and direction, significant wave height and wave direction, water level details), berthing data (terminal layout, fender properties, wharf elevation, bollard location), vessel data (vessel dimension, mooring rope diameter, fairleads, and various manifold position, winch tension) and mooring line data (diameter, materials and breaking load)
3	Heavy haulage operation	The Port operator may appoint a qualified transporter to perform this operation: experienced in handling critical project cargo Able to provide a suitable configuration of the multi-axle trailer Able to provide a transport plan, including trailer pressure calculation, stability calculation, and lashing calculation Able to conduct route surveys and risk assessments for the heavy haulage operation
4	Heavy Lifting Operation	Following the minimum standard operation procedure regulated by the National Regulation
5	Added Value Services	Open storage area for massive cargo Warehouse for sensitive cargo (height limitation and door width) Assembly and consolidation activities Inspection check by MWS Purchasing special goods Crew change
6	Port charges	Port charges (wharfage, dockage charges) Cargo handling charges (stevedores, equipment, materials)

Table 6 Heavy haulage consideration factors (Author's compilation)

Parameter	Consideration factor
Transport Route	Allowable GBP (T/m2), Route obstruction, Width/ Height limitation, Ground slope and grade resistances, the route inclination shall be less than 2%, Turning radius, overhead and lateral clearance within the route The load exerted from the heavy transport is still within the allowable GBP Number of turning points The surface ground should be even (proper maintenance to prevent any cavity on the bottom), with a solid foundation, and no sharp edges on the floor (Maoyao and Juan 2016)
Trailer Configuration	Trailer Payload has considered safety factors The configuration trailer should be within the stability area (Escribano-García et al. 2021) The minimum hydraulic stability degree is 8 degrees, and the minimum structural stability is 5 degrees (Daal 2015)
Mover truck specification	Requirement for: horsepower and tractive effort, front and rear axle rated capacity, fifth-wheel capacity, transmission reduction, and tire capacity (Bechtel 2002)
Operational risk	Technical risk, Equipment failure, Communication breakdown, Human error risk, commercial risk, and any other risks identified to generate a contingency plan

Project logistics operation

Performance evaluation for project logistics operation

One of the methods to review the productivity of the vessel carrying project cargo is by evaluating the vessel's operational efficiency using the Time Charter Equivalent (TCE) (Malaksiano and Melnyk 2020). The formulation for TCE such as follows:

$$\text{TCE} = \frac{N_F - V_c}{t_v} \tag{15}$$

where:

$N_F =$ net freight (total freight cost minus the brokerage commission).

$V_C =$ the variable cost consisting of port charges (PC), cargo handling charges (CHC), and operating cost (OC).

$t_v =$ the voyage duration in days.

This freight rate obtained from the company will be compared to the market FRTC (freight rate of the time charter for the same vessel payload (Malaksiano and Melnyk 2020).

Project logistics risk

As discussed above, the project freight is mainly for an offsite construction project. The EPC projects overseas for modular construction or any infrastructure large-scale project involves the activities required to mobilise equipment from the manufacturer site to the installation location, consisting of packing, warehousing, inspection, custom and tax declaration. Figure 4 identifies the logistics risks for overseas EPC projects. Apart from the above, there are also additional risk factors affected by natural factors (He and Han 2022) or geographical conditions such as thunderstorms, earthquakes, and tsunamis, especially for areas vulnerable to such risks. The social risks can hardly be identified in the early stage since it involves public tolerance of the projects. Social risk refers to human resources' risks, such as a total workforce,

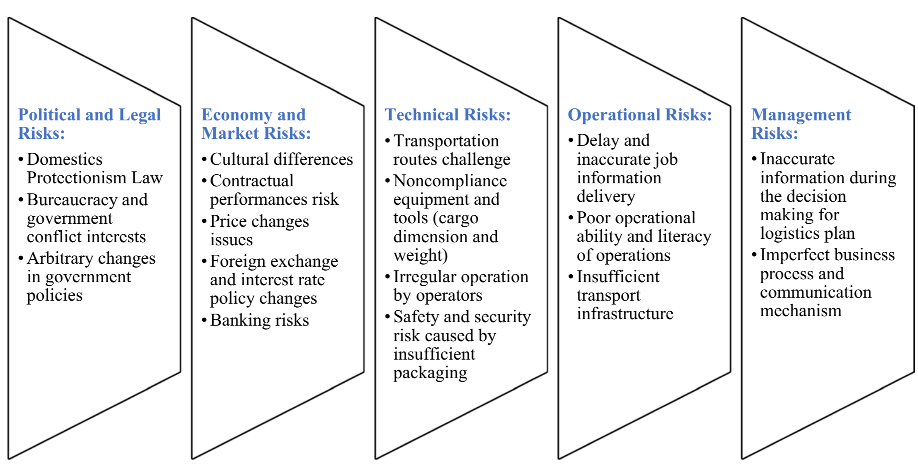

Fig. 4 Logistics risk for overseas EPC projects (He and Han 2022) (Palšaitis and Petraška 2012)

community expectations on the project, and negative attitude towards oversized and overload cargo transportation (Palšaitis and Petraška 2012).

Evaluating adverse risks before transporting the heavyweight cargo through the main road in the cities is crucial to ensure safe delivery with the minimum impact on the other traffic users. The risk (R_{ij}) of the road segment is calculated based on the accident probability (P_{ij}) multiplied by the consequences of an accident(C).

$$R_{ij} = P_{ij} x C \tag{15}$$

The accident is measured per unit of time (yearly) and location/distance (accident per vehicle kilometres). Thus, the accident for oversized cargo transportation without disrupting other road users should measure by the number of accidents within the road section (in kilometres) per given unit of time (yearly). The accident probability (P_{ij}) is calculated using Poisson distribution such as follows:

$$P_{ij} = \frac{e^{-\lambda}\lambda^k}{k!} \tag{16}$$

The annual accident rate can be calculated using the following formula (Palšaitis and Petraška 2012):

$$\mathrm{Z} = \frac{Ax1000}{dist x365} \tag{17}$$

Where: P_{ij} = accident probability

e = based of natural logarithm (e = 2.718281828)

λ = positive actual number, equal to the expected number of occurrences during the given interval

Z = annual accident rate per thousand

k = the number of occurrences of an event

$k!$ = the factorial number of k

A = the number of accidents involving heavyweight vehicles per year

dist = transportation distance

Each heavy transport accident has a few consequences, such as people injury/death, undelivered/damaged cargo, delivery delay, and damage to transport infrastructure and traffic users. The formula to calculate the consequences such as follows (Palšaitis and Petraška 2012):

$$\mathrm{C} = FHT_{ave}\mathrm{x}365\mathrm{x}W_{ave}\mathrm{x}UC_{ton} \tag{18}$$

where: FHT_{ave} = average frequency of heavyweight transport per segment (daily)

W_{ave} = average weight of the load

UC_{ton} = unit cost per ton load

Project logistics management

In the previous study, Denktaş et al. studied the enablers and barriers of project cargo logistics in Turkey. It found barriers to project logistics operation, such as poor terminal facilities, hinterland distribution interconnectivity, and government regulations, profoundly impacting project cargo logistics decisions (Denktaş Şakar et al. 2018). The complexity of the project cargo can be reduced by involving the role of the freight forwarder—Denktaş Şakar, in value creation in project cargo logistics. Denktaş's study shows that freight forwarders are considered the most crucial partner in project cargo logistics based on 80% consensus. Selecting project logistics vendors based on assets capabilities and social networking between a government and other contractors becomes crucial for the project cargo supply chain (Viswanadham and Sinha 2015). Figure 5 shows the enable and barriers of the project logistics.

The deciding factors for involving freight forwarders or NVOCC are the shippers' experience level in handling project cargo, convenience, air and sea freight requirements integration to a 3PL provider, price, and services. The most crucial deciding factor to include NVOCC is the need for carriers to provide end-to-end logistics with time-sensitive leveraging their robust networking system to simplify the logistics process, especially for international projects (Fanam and Ackerly 2019).

The need for simplifying the integration department from the production site to the distribution department has promoted the implementation of multimodal transportation in the manufacturing industries. Applying the multimodal transport concept provides benefits such as reducing the liabilities under the intermodal scheme, clear communication with one operator for contract carriage from the origin point to the final destination, and tranquil monitoring for cost, schedule, and safety throughout the operational process (Turbaningsih et al. 2021).

Planning of project cargo logistics requires an integrated planning approach that considers the following aspects: total delivery cost management, global logistic process automation, end-to-end visibility, transport routing management, variability management, integrated international and domestics workflow, comprehensive product identification and regulation compliance, and financial supply chain management (Carriker and Langar 2006). The integration of stakeholders in the project logistics should involve the element of relationship marketing consisting of (1) trust (the benevolences and credibility among relationship partners), (2) customer satisfaction (outcome achieved by collaborating partners, and (3) commitment (maintaining long-term orientation) (Osobajo et al. 2021). Those key relationships reduce project

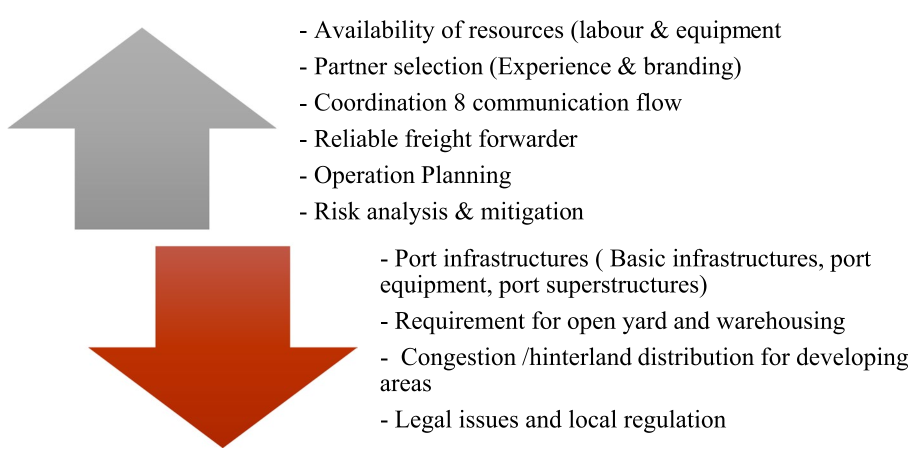

Fig. 5 Enablers and barriers of the project logistics (Denktaş Şakar et al. 2018)

failure risk and improve maritime supply chain performance. The integration should promote the efficiency of end-to-end logistics.

Conclusion and future research

Project logistics is not a popular subject for research because of its unique characteristics that require special consideration during in planning and operation. The project freight is generated from the technology development in the construction industry. The efficiency in the project logistics will directly affect the infrastructure construction cost.

The project supply chain requires the integration of all sectors from the business institution, social and governmental sectors, and logistics players. The transport planner should consider the commercial, technical, and safety as part of the integrated multidisciplinary planning. The technical and safety evaluation is a priority to ensure safe delivery without any damage to the cargo by selecting the optimum marine transport fleet, land transport system, suitable port infrastructure, and personnel involved in loading/discharging oversized cargo. In the port operation, the planning should include activities for berthing, mooring, heavy haulage, heavy lifting, port charges, added value services such as storage, assembly, minor fabrication, inspection by MWS, and other special services.

In terms of commercial aspects, applying the multimodal transport concept provides benefits such as reducing the liabilities under the intermodal scheme and tranquil monitoring for cost, schedule, and safety throughout the operational process. The optimisation for selecting the combination scheme for land transport and marine transport utilises the priority level for the total logistics cost, delivery time and probability of damage. This study aims to contribute in the project cargo development as a guide multidiscipline studies that combine both technical and commercial aspects of project cargo logistics.

For future research, it is recommended to provide a freight generation model for renewable energy infrastructure and an optimisation model to plan the transportation for renewable energy products and modular structure products. It is also recommended to create a model using Mixed Integer Linear programming to perform project cargo planning to obtain optimum outcomes such as vessel routing, hub port decision, and scheduling.

Abbreviations

AHP	Analytical hierarchy process
CoG	Centre of gravity
DNV	Detnorske veritas
FRTC	Freight rate time charter
GBP	Ground bearing pressure
MCA	Multi-criteria analysis
MHC	Mobile harbour crane
OoG	Out of gauge
POD	Port of discharging
POL	Port of loading
SPMT	Self-propelled modular trailer
TCE	Time charter equivalent

Author contributions

This study aims to contribute in the multidisciplinary studies that integrated technical, commercial and safety aspects in the project logistics field. It is necessary to optimise the total logistics cost in the construction industry. All authors read and approved the final manuscript.

Competing interests

The author declares that they have no competing interests.

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References

Carriker M, Langar S (2006) Factors Affecting Large Scale Modular Construction Projects. 50th ASC Annu Int Conf Proc 2014:1–8.

Denktaş Şakar G, Yıldırım E, Mansuroğlu E (2018) Value creation in project cargo logistics: a delphi study. J ETA Marit Sci 6(3):255–274

Drewry. (2002) Shipping insight

Escribano-García R, Corral-Bobadilla M, Somovilla-Gómez F, Lostado-Lorza R, Ahmed A (2021) A theoretical model with which to safely optimise the configuration of hydraulic suspension of modular trailers in special road transport. Appl Sci 11(1):1–17

Fanam PD, Ackerly L (2019) Evaluating ocean carrier selection criteria: perspectives of Tasmanian shippers. J Shipp Trade. https://doi.org/10.1186/s41072-019-0042-9

Flory JF, Banfield SP, Ractliffe A (1998) Computer mooring load analysis to improve port operations and safety [Internet]. Vol 2 Ports - Proceedings. Sussex: tension technology international, Ltd; 1998 [cited 2021 May 15]. p. 840–9. Available from: https://www.tensiontech.com/papers/optimoor

GL Noble Denton. Guidelines for marine lifting & lowering operations 0027/ND [Internet]. GL D, editor. 2015a. 1–84 p. Available from: http://rules.dnvgl.com/docs/pdf/gl/nobledenton/0027-nd rev 11.2 8-Jul-16 guidelines for marine lifting and lowering operations.pdf

GL Noble Denton (2015b) Guidelines for loadout 0013/ND. Hamburg, p 1–39

GL Noble Denton (2016) General guidelines for marine projects DNV 0001/ND. Hamburg

Hanssen T-ES, Mathisen TA, Jørgensen F (2012) Generalized transport costs in intermodal freight transport. Procedia Soc Behav Sci 54:189–200. https://doi.org/10.1016/j.sbspro.2012.09.738

He J, Han D (2022) Evaluation of key factors of logistics risks for overseas EPC projects. Adv Civ Eng 2022

IEA (2022) Global hydrogen review 2022 [Internet]. Global hydrogen review 2022. 2022. Available from: https://iea.blob.core.windows.net/assets/c5bc75b1-9e4d-460d-9056-6e8e626a11c4/GlobalHydrogenReview2022.pdf

Jiang Y, Zhao D, Wang D, Xing Y (2019) Sustainable performance of buildings through modular prefabrication in the construction phase: a comparative study. Sustain 11(20):5658

Jones M (2005) Supply chain management in construction. Constr Proj Manag an Integr Approach 3:308–339

Jurong Port (2022) Next generation multipurpose port [Internet]. [cited 2022 Aug 1]. Available from: https://www.jp.com.sg/

Kaiser MJ (2015) Offshore service industry and logistics modeling in the gulf of Mexico [Internet]. Springer International Publishing, Cham

Kamali M, Hewage K (2016) Life cycle performance of modular buildings: a critical review. Renew Sustain Energy Rev [internet] 62:1171–1183. https://doi.org/10.1016/j.rser.2016.05.031

Lai K, Pang Y, Wong CWY, Lun YHV, Ng YNE (2019) Are trade and transport logistics activities mutually reinforcing? Some empirical evidences from ASEAN countries. J Shipp Trade. 4(1):1–7

Leach R P (2002) Bechtel rigging handbook (Second Edition). 190

Macioszek E (2019) Conditions of oversize Cargo transport. Sci J Silesian Univ Technol Ser Transp 102:109–117

Malaksiano MO, Melnyk OM (2020) Vessel selection prospects and suitability assessment for oversized Cargo transportation. Sci Notes Taurida Natl VI Vernadsky Univ Ser Tech Sci 2(1):135–140

Maoyao Z, Wang J (2016) Load-out Design of Jacket With SPMT. (Iccte): 224–28

McKinsey & Company. Modular construction: from projects to products [Internet]. Capital projects & infrastructure. 2019. Available from: https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/modular-construction-from-projects-to-products

Melnyk O, Malaksiano M (2020) Effectiveness assessment of non-specialised vessel acquisition and operation projects, considering their suitability for oversized cargo transportation. Trans Marit Sci 9(1):23–34

Melnyk O (2022) The method of determining the optimal scheme of project Cargo delivery method

El Noshokaty S (2017) (2017) Shipping optimisation systems (SOS): tramp optimisation perspective. J Shipp Trade 2(1):1–36

Notteboom T, Athanssios P, Rodrigue J-P (2021) The insertion and location of transshipment hubs. In: Routledge (ed) Port Economics, management and policy. Routledge, New York

Onyshchenko S, Shibaev O, Melnyk O (2021) Assessment of potential negative impact of the system of factors on the ship's operational condition during transportation of oversized and heavy cargoes. Trans Marit Sci 10(1):126–134

Osobajo OA, Koliousis I, McLaughlin H (2021) Making sense of maritime supply chain: a relationship marketing approach. J Shipp Trade 6(1):1–17

PIANC Secrétariat Général (2014) Harbour approach channels desing guedlines - report No 121–2014. Brussel.

Pache H (2019) Current state and trends in tramp ship routing and scheduling

Palšaitis R, Petraška A (2012) Heavyweight and oversized cargo transportation risk management. Transp Telecommun 13(1):51–56

Petru J, Krivda V (2021) The transport of oversized cargoes from the perspective of sustainable transport infrastructure in cities. Sustain 13(10):5524

Santos, Tiago A. ; Soares CG. Maritime Supply Chains. In: Vanelslander, Thierry Sys C, editor. Maritime supply chains. Amsterdam: Elsevier; p 17–37

Song D (2021) A literature review, container shipping supply chain: planning problems and research opportunities. Logistics 5(2):41

Stopford M (2013) Maritime economics. Taylor & Francis, London

Subiyanto E, Totok Y (2020) Heliyon determining value of logistics costs in projects : empirical findings based on executing several cement projects in Indonesia. Heliyon [Internet] https://doi.org/10.1016/j.heliyon.2020.e04352.
Turbaningsih O (2014) Vessel mooring analysis and ignition range dispersion analysis for LNG. Jurnal Teknologi 7:173–180
Turbaningsih O, Buana IGNS, Nur HI (2022) The multimodal transport analysis for project logistics : export from Indonesia to Bangladesh. Cogent Soc Sci [internet]. 8(1):1–13. https://doi.org/10.1080/23311886.2022.2095081
Turbaningsih O, Mutaharah U (2022) The adaptive engineering asset management framework for sustainable gas terminal infrastructures. IOP Conf Ser Earth Environ Sci 1081(1):012012
Turbaningsih O, Nur W, Nisa H, Mustakim A. The study of adaptive planning application for LNG regasification terminal infrastructure in Indonesia 1.
UK P&I Club (2018) Carefully to Carry. In: carefully to carry. 1st ed. Witherby Publishing Group Ltd, Livingston
UNCTAD (1991) Multi-purpose port terminals. Recommendations for planning and management [Internet]. UNCTAD Monograph on Port Management. Madrid. Available from: https://unctad.org/system/files/official-document/ship4949_en.pdf
van Daal M (2015) Reference time. International crane and specialized transport 47–51
VTPI (2017) Transportation cost and benefit analysis II – vehicle costs. In: victoria transport policy institute [Internet]. British Columbia: Victoria transport policy institute 1–16 Available from: http://www.vtpi.org/tca/tca0501.pdf
Viswanadham N, Sinha NK (2015) Design of project Cargo logistic network: an ecosystem framework. Heavy Haulers, UK
Vrijhoef R (2011) Supply chain integration in the building industry: the emergence of integrated and repetitive strategies in a fragmented and project-driven industry [Internet]. 321 p Available from: https://books.google.com/books?hl=en&lr=&id=34p26fH5Z_kC&pgis=1
Wijnolst N, Wergeland T (2009) Shipping innovation, 1st edn. IOS Press BV, Amsterdam, pp 334–356
Wolnowska AE, Konicki W (2018) Multi-criterial analysis of oversize cargo transport through the city, using the AHP method. Transp Res Procedia [internet] 2019(39):614–623. https://doi.org/10.1016/j.trpro.2019.06.063
Zheng M, Wang J (2016) Load-out design of jacket with SPMT. 224–8

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