Workshop Proceedings:

Improving Modular Constuction: Management & Technical Advancements

- Tues 14 October 2014

European Construction Institute

Workshop on

Improving Modular Construction: Management & Technical Advancements

Tuesday 14 October 2014

Loughborough University,
Loughborough, UK

eci European Construction Institute

in conjunction with:

ECITB Engineering Construction Industry Training Board

Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

Attendees List

Name	Company
Adrian Fenton	AMEC
Alessandro Palmeri	Loughborough University
Alistair Gibb	ECI
Andrew Till	BP
Brian Champkins	M+W Group UK
Bruce Douglas	AVEVA
Callum Alderton	Loughborough University
Chris Goodier	Loughborough University
Danny Leighton	BG Group
David Adamson	Sellafield Limited
David Yates	Franklyn Yates Engineering Limited
Diego Gil	Fluor
Edwin Daniels	Fluor
Federico Perotti	Politecnico di Milano
Gytis Juodzevicius	KBR
Iain MacPhee	Fluor
Igor Lyullin	Loughborough University
James Bishop	ECI
John Frodsham	BG Group
Jonathan Jenner	Air Products

in conjunction with:

Workshop on Modular Construction: Management & Technical Advancements

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Attendees List

Name	Company
Keerthivasan Jayaraman	KBR
Mark Sadler	Mammoet
Michael O'Connor	Mercury Engineering
Patrick Pady	Fluor
Paul Bonaccorsi	Intelligent Offsite
Paul Sloan	Sellafield Limited
Paul Smith	AMEC
Rees Brislin	CB&I
Robby Soetanto	Loughborough University
Timothy Spurgeon	Air Products
Tony Goddard	M+W Group UK
Thiruvalluvar Janahan	Loughborough University

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PROGRAMME

09:30 Registration and Coffee

Welcome

10.00 Introduction to Workshop & ECI

James Bishop, ECI

Presentation 1 - Paul Sloan, Sellafield

10:45 Coffee and Networking break

Presentation 2 - Patrick Pady, Fluor

Presentation 3 - Mark Sadler, Mammoet

12:15 Networking Lunch

Presentation 4 - Federico Perotti, Politecnico di Milano

Presentation 5 - Alistair Gibb, Loughborough University

14.15 Group Discussion Session

15.15 Feedback Session

16.15 Closing Remarks

Presentation slides

for

Paul Sloan

Sellafield

in conjunction with:

Engineering Construction Industry Training Board

Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

Paul Sloan
Head of Construction
Sellafield Limited

Paul is a mechanical engineer with experience of project delivery from both Client and Contractor perspective. He has held roles across the whole project lifecycle, having previously worked within Design organisations, managed manufacturing contracts, led construction and installation of active cells, commissioned major projects and been successful in winning and delivering works in the nuclear decommissioning sector.

Paul is native West Cumbrian and has worked on the Sellafield site since 1986, having previously worked in the manufacturing industry. He is currently Sellafield Limited Head of Construction, where he is responsible for establishing and maintaining construction procedures, introducing/utilising Knowledge Management to bring about project delivery improvements and also responsible for the standards applied to Construction Management roles across Sellafield project management organisation.

Sellafield Ltd

A Nuclear Management Partners company
operated under contract to the NDA

Modularisation

A Client Perspective

Date: October 2014

Modularisation - A Client Perspective

- Sellafield – Currently UK's Largest Construction Site.
- Why?
  - Responsible for the 'Aftercare and Clean Up' of the UK Nuclear legacy
  - Ageing Storage and Treatment facilities to be replaced
  - Continued commitment to reprocessing contracts
  - Ever changing environment

Modularisation - A Client Perspective

- Sellafield Ltd (SL) Project Drivers
  - Time - Ageing Facilities/Reprocessing Capacity
  - Cost - Efficient use of UK Taxpayer monies
  - Quality – Nature of Materials drives exacting standards

Modularisation - A Client Perspective

- SL Project Drivers (Sub)
  - Complexity of Design
  - Access to Site
  - Capacity & Capability of Local Supply Chain
  - Site Constraints/Build Sequence
  - Proximity to adjacent ‘live’ facilities
  - Etc

Modularisation - A Client Perspective

- Evaporator D
  - Schedule Driven Project

A Nuclear Management Partners company operated under contract to the NDA
Sellafield Ltd

Modularisation - A Client Perspective

- Evaporator D
- Where does this take the decision process?
  - Modularisation allows parallel activities/multiple workfronts
  - Build Remote from Site – Local Capacity/Capability?
  - Road network in West Cumbria
  - Rail network in West Cumbria
  - Sea Transportation – most viable option

Modularisation - A Client Perspective

- Evaporator D
  - Engineering
    - Extensive Temporary works
    - Increased duty due to transportation stresses
    - Reduced clearance in-cell for installation phase
    - Build Sequence & access arrangements – limits flexibility

Modularisation - A Client Perspective

- Evaporator D
  - Intelligent Customer Oversight
    - Temptation to treat as 'simple procurement' exercise
    - Far from simple – Sub Project
    - Internal 'scarce resource' now located at works

Modularisation - A Client Perspective

- Evaporator D
  - Stakeholder Management
    - Internal – site roads and infrastructure, safety case – impact with adjacent operational facilities
    - External – multiple – Police/Highways Agency, Rail Networks, Port Authorities, Local Land Owners

Modularisation - A Client Perspective

- Sludge Packaging Plant 1
  - Balance of Risk

Modularisation - A Client Perspective

- Proximity of construction site – close to ‘active facility’.
  - Safety case – dropped load (module) onto active facility (high consequence) balanced against ‘stick build’ (personnel dose uptake)

Modularisation - A Client Perspective

- Sellafield Product & Residues Store (SPRS)
  - Maximise Commissioning Opportunities – Time, Cost & Quality Driven.

Modularisation - A Client Perspective

- SPRS
  - Complex mechanical handling plant
    - Assemble at works – parallel to main civil build
    - Assemble at works – implement Integrated Works Testing
      - ‘Flush Out’ problems early and fix at works
      - Familiarise with assembly
      - Train operators

Modularisation - A Client Perspective

- Conclusions
  - Benefits are multiple and across all project drivers
  - Providing…….
    - Modularisation is designed into the whole project delivery strategy
    - All parties understand their role in delivery
  - It isn’t the silver bullet to all project problems and requires careful forethought/planning

European Construction Institute

Presentation slides

for

Patrick Pady, Fluor

and

Diego Martín Gil, Fluor

European Construction Institute

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Patrick Pady
Department Manager - Civil, Structural and Architectural Group
Fluor UK

Patrick Pady is the Department Manager for the Civil, Structural and Architectural Group at Fluor UK, Farnborough and is responsible for the technical execution of a range of global FEED and EPC Projects within the Oil & Gas, Power, Industrial and Mining sectors. These include many projects featuring various types of modular construction.

Prior to joining Fluor, Patrick was Chief Civil/Structural Engineer at Shaw Stone and Webster in Milton Keynes and Principal Civil/Structural Engineer at Foster Wheeler Energy, Reading.

Patrick is a graduate of University College Swansea and a Chartered Civil Engineer.

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Diego Martín Gil
Area Lead / Core Team Senior Engineer
Fluor UK

Diego Martín Gil is Area Lead / Core Team Senior Engineer at CSA Department, FLUOR UK. He specialises in Oil & Gas Modularisation projects.

Prior to joining FLUOR, Diego coordinated international projects across other Oil and Gas companies such as Técnicas Reunidas and Foster Wheeler Iberia. In another professional experience at Isolux Corsán, in the position of Building Division Director, he ruled the commercial and residential company activities.

Diego started his career focused in FE, collaborating in the development of CivilFEM ANSYS module at Ingeciber and as a FE tunnel design engineer at Geoconsult.

Diego obtained his PhD from Madrid Polytechnic University, where he worked as an Associate Professor for 12 years.

Modularisation: Best Practice

FLUOR

Fluor – Corporate Executive Overview

- One of the world's leading publicly traded engineering, procurement, construction, maintenance, and project management companies
- **#110** on the FORTUNE 500 list in **2013**
- Over **1,000** projects annually, serving more than **600** clients in **79** different countries
- **40,000** employees executing projects globally
- Offices in **31** countries on **6** continents
- Celebrated **100** years in **2012**

Fluor Corporate Headquarters
Dallas, Texas

FLUOR

Fluor UK Overview

- Farnborough is a leader in innovative EPC contracting and project execution strategies for mega projects
  - Full service offering:
    - Conceptual/FEED/Detailed Engineering
    - Procurement
    - Construction Management
    - Start-Up
    - Commissioning
  - UK, Europe, Africa, Middle East, Former Soviet Union and Kazakhstan
  - Energy & Chemicals, Power, Mining & Metals, Industrial Services
  - 1800 staff
  - Proven distributed execution platform
  - Joint Ventures
  - Reimbursable and Lump sum
  - Modularisation Expertise
  - FSU Regulatory Expertise

Modularisation: Best Practice

CONTENTS

- **1. Modularisation in Fluor - Recent Experiences**
- **2. Factors Driving Fluor Modular Construction Decision**
- **3. Fluor Modularisation Methods - Examples**
  - I. Pre assembled structures.
  - II. Mega Modules.
  - III. 3rd Generation Modules.
- **4. Best Current Practice - Fluor Experience.**
- **5. Q&A.**

Modularisation: Best Practice

1. Modularisation in Fluor - Recent Experiences

Modularisation: Best Practice

- 1. Modularisation in Fluor - Recent Experiences.

Modularisation: Best Practice

- **1. Modularisation in Fluor - Recent Experiences**
  - Fluor has utilised modularisation on projects since 1970's
  - Many global module projects with water access + VLMS
  - Globally some remote landlocked project locations use modules
  - Alberta Oil sands projects; landlocked locations commonly use 3rd Generation modular execution

Modularisation: Best Practice

2. Factors driving Fluor modular construction decision

Modularisation: Best Practice

- **2. Factors driving Fluor modular construction decision**
  - Main factor groups to be analysed are as follows:
    - Organization's Readiness
    - Owner's Willingness
    - Economic drivers
    - Module-related drivers
    - Fabrication/quality issues
    - Logistics and equipment drivers
    - Location specifics / regulations
    - Labour considerations
    - Specific Project risks
    - Environmental requirements

Modularisation: Best Practice

- **2. Factors driving modular construction decision**
  - Factors that support module design:
    - Remote site
    - Severe site climate constraints
    - Schedule improvements
    - Plot Plan constraints
    - Limited availability of regional skilled labour/ imported construction labour/ man camps
    - Extensive Factory Acceptance Testing (FAT) desired
    - High module potential / repeatability
    - High density piping, cabling

Modularisation: Best Practice

- **2. Factors driving modular construction decision** (Example)
  - *Plot Plan constraints*

Conventional Unit Plot Plan

Modularisation: Best Practice

- **2. Factors driving modular construction decision** (Example)
  - *Plot Plan constraints*

3rd Generation Modularised Unit Plot Plan

Modularisation: Best Practice

3. Fluor Modularisation Methods - Examples

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Modularisation: Best Practice

- **3. Fluor Modularisation Methods - Examples**
  - I. Pre-assembled structures
  - II. Mega Modules
  - III. 3rd Generation Modules
  - *To consider:*
    - *Every project has unique requirements*
    - *Every module fabricator has unique methods / capabilities*
    - *Every Client has unique preferences*
    - *Every engineer has a unique way to design a module.*

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Modularisation: Best Practice

- **3. Modularisation methods (I).** Pre-assembled structures

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Modularisation: Best Practice

- **3. Fluor Modularisation Methods (I).**
- Pre-assembled structures
  - Middle Eastern EPC Project
    - Offsites & Utilities Petrochemicals Facility Project
    - Common Facilities Interconnecting Pipe Racks
    - Multiple Projects, Multiple Contractors
    - Congested Site, Limited Laydown on site
    - Large Labour Force
    - Climate
  - FEED featured stick-built, bolted steel structures
  - Fluor Challenge – to offer project the advantages of modularisation at no extra cost

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- **3. Modularisation methods (I).**
- Pre-assembled structures.
  - Method Adopted
    - Outdoor Pre-assembly yard adjacent to site, 3km
    - Fabricated steelwork delivered piece-small to pre-assembly yard. Bolted construction
    - Optimised design process, weight saving. NO additional bracing or transportation steel
    - Structures erected on stools in yard including piping, cable trays, ladders, handrail etc.
    - Controlled SPMT load out, transportation and placement strategy developed in close consultation with transportation contractor
    - 4 point support to avoid instability
    - PAR's Placed onto Precast Concrete columns

Modularisation: Best Practice

- **3. Modularisation methods (I).** Pre assembled structures.

Modularisation: Best Practice

- **3. Modularisation methods (I).** Pre-assembled structures.

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Modularisation: Best Practice

- **3. Modularisation methods (I).** Pre-assembled structures.

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Modularisation: Best Practice

- **3. Modularisation methods (I).** Pre-assembled structures.
  - Other Applications
    - Pipe Support Structures
    - Equipment Skids
    - Pancakes
    - Prefabricated Buildings
    - Package Substations, Switchgear Rooms
    - Pre-dressed columns and vessels

Modularisation: Best Practice

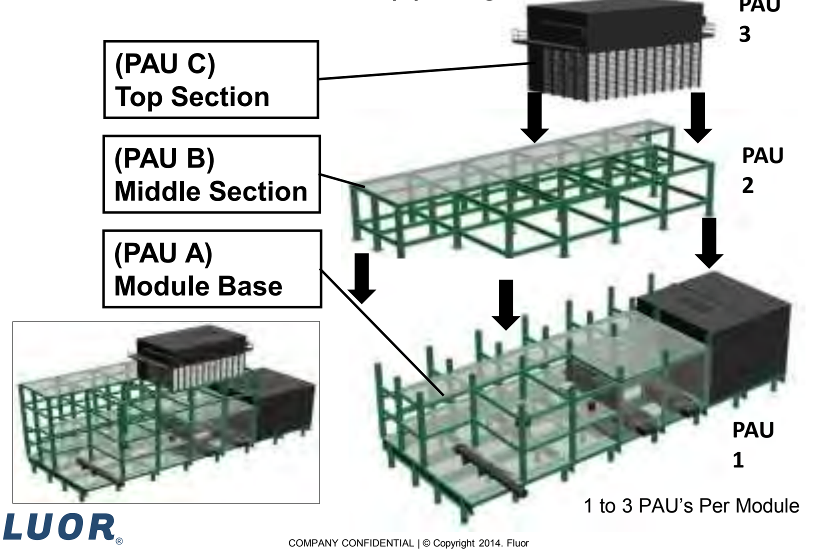
- **3. Modularisation methods (II).** Mega Modules

Modularisation: Best Practice

- **3. Modularisation methods (II).** Mega Modules.
  - Constraints
    - Module definition. Limits related to weight (>>600t) and dimensions. (Land+ Sea transportation)
    - Heavy Haul contractor input at the early stages: accelerations, grillage concept, hog/sag…
    - Requirements related to vessels / Infrastructure
    - Feasible fabrication locations
    - Module standardisation vs. material saving
    - Stacked /Non Stacked transportation

Modularisation: Best Practice

- **3. Modularisation methods (II).** Mega Modules

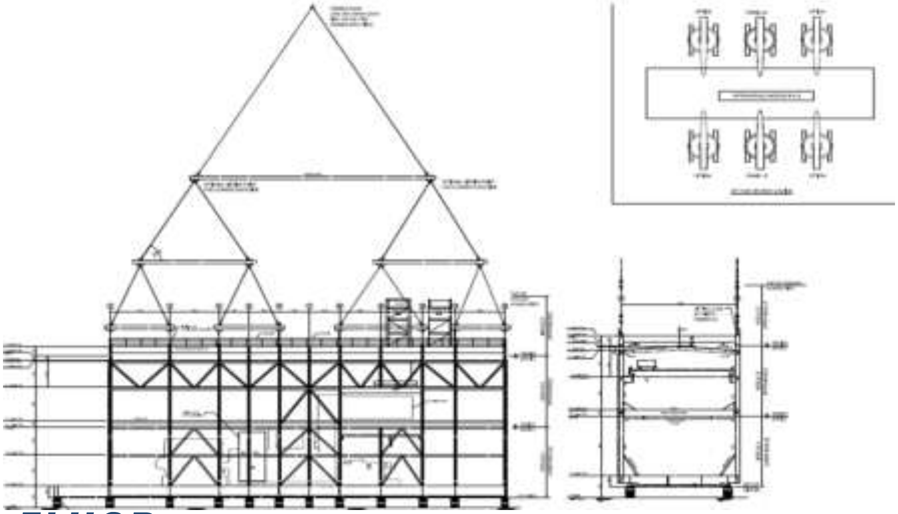


1 to 3 PAU's Per Module

Modularisation: Best Practice

FLUOR Celebrating 100 years

- **3. Modularisation methods (II).** Mega Modules.



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Modularisation: Best Practice

FLUOR Celebrating 100 years

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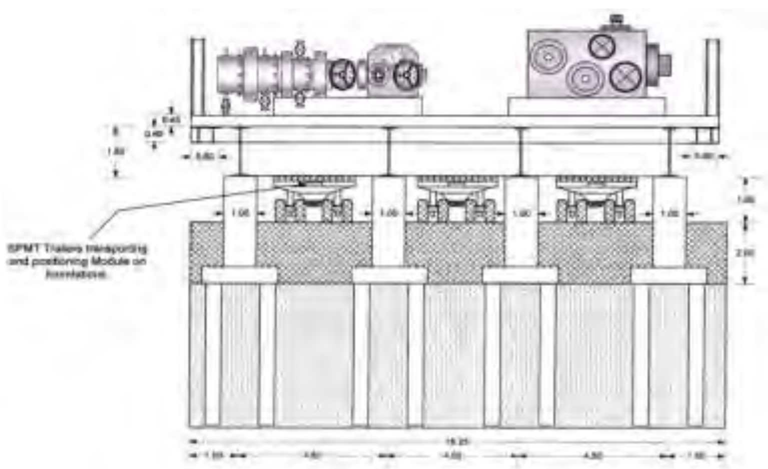

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Modularisation: Best Practice

- **3. Modularisation methods (II).** Mega Modules.

Modularisation: Best Practice

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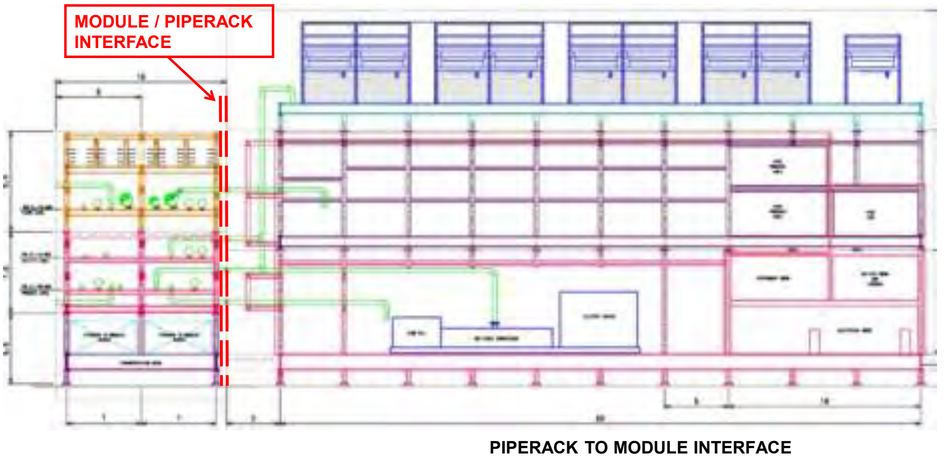

PIPERACK TO MODULE INTERFACE
STANDARDISED ELEVATIONS

Modularisation: Best Practice

- **3. Modularisation methods (II).** Mega Modules.

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Modularisation: Best Practice

- **3. Modularisation methods (III).** 3rd Generation Modules.

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Modularisation: Best Practice

- **3. Modularisation methods (III).** 3rd Generation Modules.
  - Fluor has developed a 3rd Gen Modular Execution Methodology, considering:
    - Past modular projects and Offshore design methods
    - Facility interconnections
    - Power and control distribution
  - Key factors:
    - Minimise site labour. Relocate 90% field hours to fabrication yard
    - "Modularization Drives Layout" not "Layout Drives Modularization"
    - Schedule/Vendor interdependencies are critical to success
    - Minimise foundations activities
    - Avoid piperacks- integrate into structures
    - 95%steel & 95%piping on modules
    - 85%electrical & 95%instruments on modules
    - Cabling, wiring & testing at fabrication yard
    - Equipment commissioning at fabrication yard

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Modularisation: Best Practice

- **3. Modularisation methods (III).** 3rd Generation Modules.

COST ACCOUNT	Quantity Delta 2nd Gen to 3rd Gen
Excavation, Backfill & Piling	-35%
Concrete	-60%
Structural Steel	+20%
Buildings	-20%
Mechanical Equipment	0%
Piping	-20%
Electrical	-30%
Instrumentation	0%
Insulation	-20%

NOTE: Percentages are specific for each project

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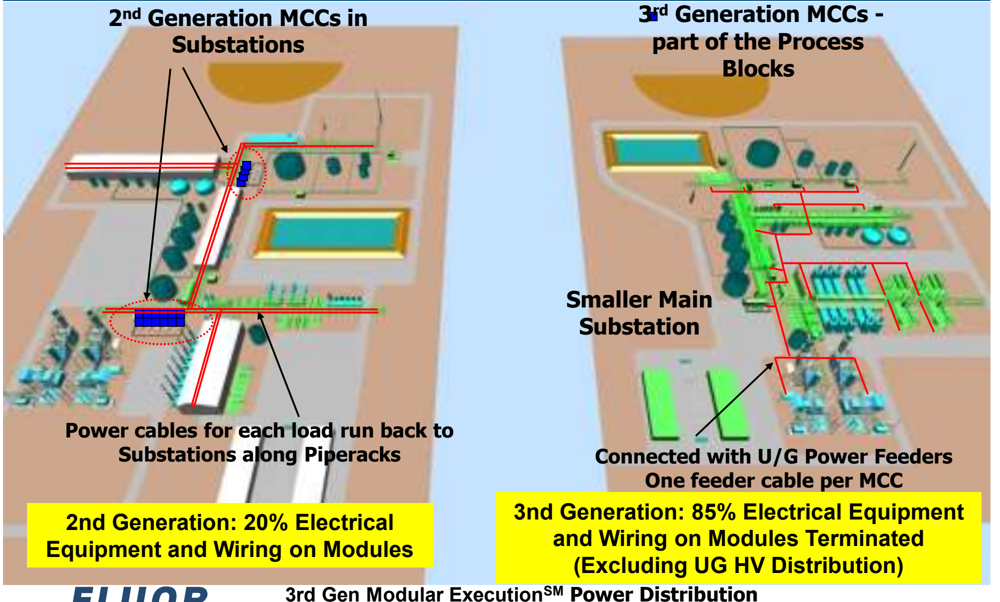
Modularisation: Best Practice

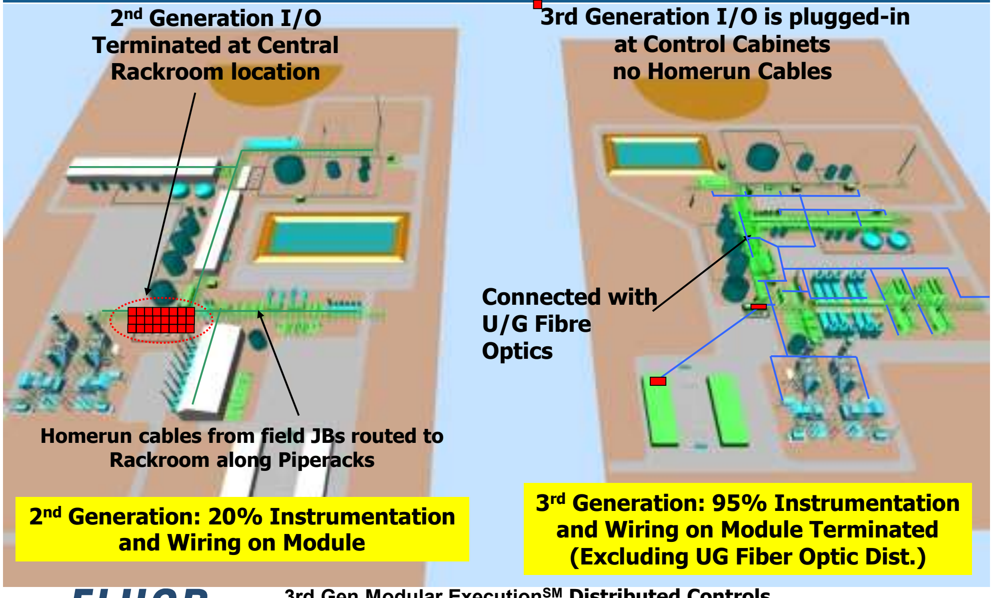
- **3. Modularisation methods (III).** 3rd Generation Modules.

Modularisation: Best Practice



3rd Gen Modular Execution^{SM} Power Distribution

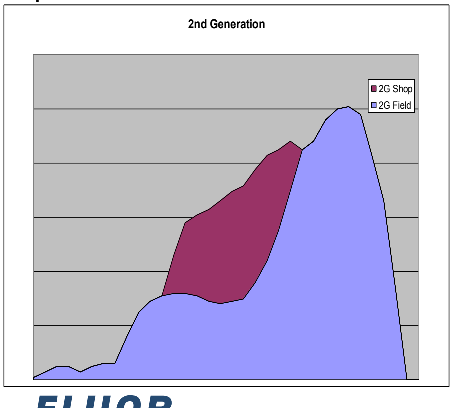
Modularisation: Best Practice

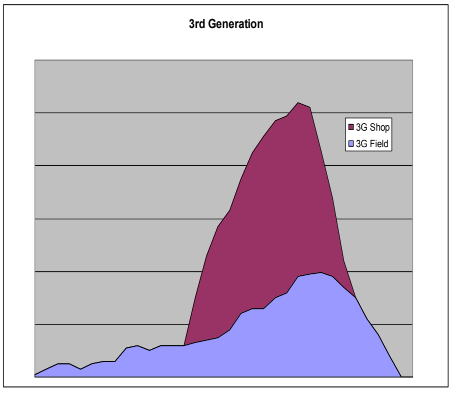


FLUOR 3rd Gen Modular Execution[SM] Distributed Controls

Modularisation: Best Practice

- **3. Modularisation methods (III). 3rd Generation Modules.**
  - **Direct Craft Staffing Comparison**
    - Managing and achieving a steep manpower decline in the shop is easier than in the field.





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Modularisation: Best Practice

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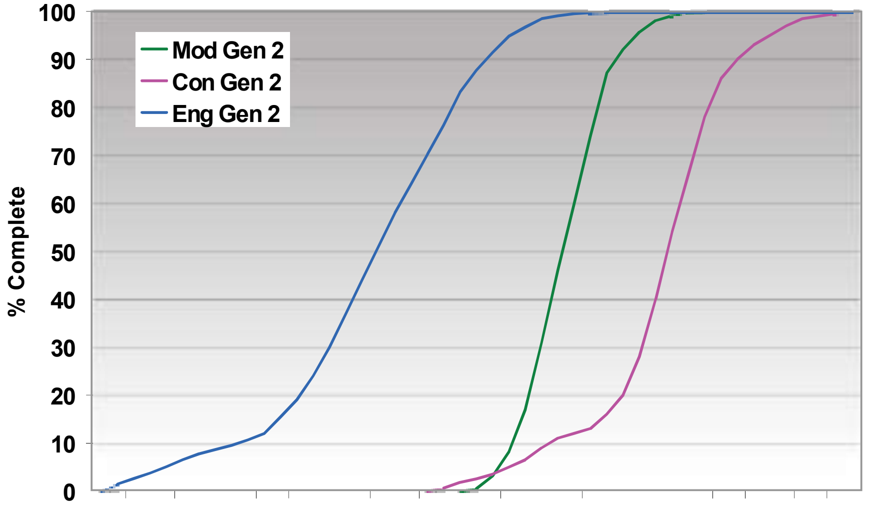

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Modularisation: Best Practice

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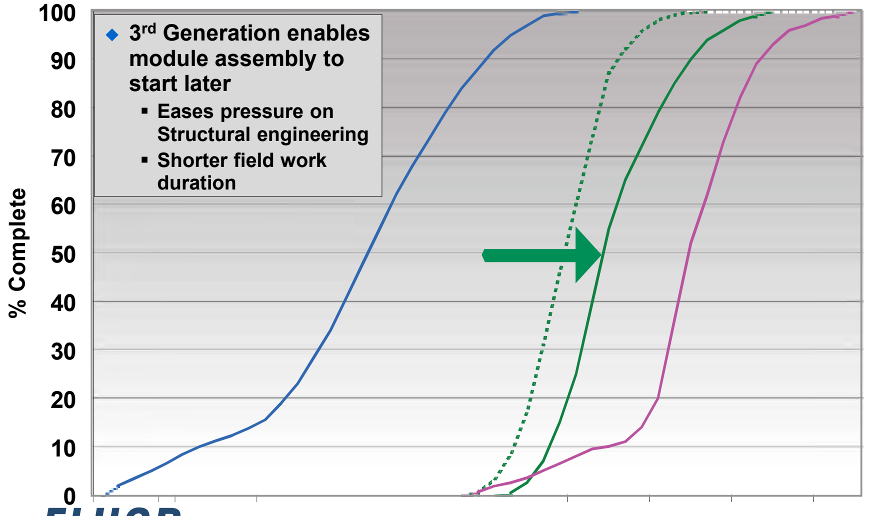

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Modularisation: Best Practice

◆ **3. Modularisation methods (III).** 3rd Generation Modules.

Modularisation: Best Practice

4. Best Current Practice - Fluor Experience

Modularisation: Best Practice

- **4. Best Current Practice - Fluor Experience**
  - **4.1. General**
    - Understand the implications of modularization on engineering work processes
      - Piping and Structural are usually aligned and understand the level of effort required
      - Electrical, Control Systems and HVAC may have to accelerate their work
      - Process and Mechanical to recognise the restrictions caused by modularization
    - Contingency Plans
      - Bear in mind that something will go wrong along the way
      - Consider different scenarios
      - Identify risks and contingency measures

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Modularisation: Best Practice

- **4. Best Current Practice - Fluor Experience**
  - **4.2. Early engagement with Logistics and their contractors**
    - Logistics
      - Firmly define any geometric/weight restrictions (max envelope / weight)
    - Naval Architect/Marine Warrantor
      - Transit Routes, Metocean Data and Marine Transport Analyses
      - Project documentation for warrantor
    - Marine Contractor
      - Vessel types and availability
      - Verify method of Load out
      - Coordinate on Grillage and Seafastening designs
    - Heavy Haul Contractor
      - Transport/Transit Routes
      - Transporter Types
    - Heavy Lift Contractor
      - Craneage and rigging capabilities
      - Lift plans & space required

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Modularisation: Best Practice

- **4. Best Current Practice - Fluor Experience**
  - **4.3. Early engagement with Fabricator**
    - 75% of engineering finished before fabrication starts
    - Client/project taskforce to understand selected fabricators work history and tendencies
    - Achieve alignment on project specifications and standards
      - Material finish including Galvanising and Fireproofing
      - Miscellaneous Supports
    - Achieve alignment on work processes
      - 2D drawings or 3D model transfer
      - Dimensional Control Procedures
    - Achieve alignment on commissioning philosophy
    - Achieve alignment on preservation philosophy
    - Develop EPC schedule around fabricator capabilities
    - Maximise understanding of contractual obligations to minimise potential future claims

Modularisation: Best Practice

- **4. Best Current Practice - Fluor Experience**
  - **4.4. Early engagement with Construction**
    - Early definition of construction strategy
    - Define staging and storage areas
    - Develop on-site transport routes
    - Coordinate with logistics contractors on module installation procedures
    - Coordinate with surveyors and dimensional control representatives
    - Define inter-module hook-up philosophy
    - Local Labour Regulations
    - Modules onsite ideally 3 months prior to placement

Modularisation: Best Practice

- **4. Best Current Practice - Fluor Experience**
  - **4.5. Develop and implement Weight Control Program**
    - Establish weight reporting format and cycles
    - Establish datum and tolerable centre of gravity locations
    - Establish weight shedding guidelines and other contingency measures
    - Coordinate with engineering, fabricator and logistics contractors on physical weighing procedures
    - Ensure Client and project taskforce are aware of the purpose and criticality of formal weight control programs

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Modularisation: Best Practice

- **4. Best Current Practice - Fluor Experience**
  - **4.6 Problems to AVOID!**
    - Modularization strategy and plan developed too late
    - Modules incomplete at shipment
    - Late engineering deliverables or late revisions
    - Instrument, electrical,... materials late
    - Modules delivered late and/or in wrong sequence
    - Shop workload exceeds capacity

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Modularisation: Best Practice

THANKS FOR YOUR ATTENTION.

Q&A

Presentation slides

for

Mark Sadler

Mammoet

European Construction Institute

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Mark Sadler
Senior Commercial Manager – Projects
Mammoet

Mark Sadler became Senior Commercial Manager for Mammoet in Jan 2014. He joined the company in 2008 as an engineer after graduating from the University of Hertfordshire in Aerospace engineering. His early career was spent on various different projects within the UK which covered the full range of services which Mammoet offer. From replacing large columns and vessels on different petrochemical sites to installation of new bridges around the UK.

He built up a good knowledge of the market and moved to a projects engineer/management role within the company in 2010. Engineering and organising the projects he was involved with from an operational point of view he built up a network of key personnel within both the Mammoet organisation and our customer base.

In 2011 he was asked to move into Mammoet's sales department as a commercial manager. Earlier this year he was made responsible for the UK Projects sales business. He enjoys keeping up to date with the technological advances which Mammoet are making in Heavylift and transport bringing new innovation to the market.

MAMMOET IN BRIEF

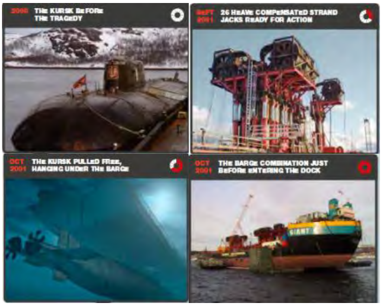
- Mammoet is a global specialist in heavy lifting & transportation projects
- Assist clients in delivering improved construction efficiency and optimize the operational time of their plants, facilities & installations with services and solutions for the safe lifting, transporting, installing and decommissioning of large or heavy structures
- More than 1,600 cranes ranging from 5te to 3,600te capacity
- More than 4,000 axle lines of modular transporter providing a total capacity in excess of 120,000te
- In total some 110,000te capacity of hydraulic jacking & skidding equipment
- Employees: 5,000

MAMMOET

MAMMOET IN BRIEF

'LONDON EYE'

'THE KURSK'



MAMMOET

COMMON CHALLENGES

- Historically construction always via 'stick built' piece small approach
- No heavy load route / infrastructure available for oversize modules
- No quayside at site for direct shipment
- Stakeholders with limited knowledge and understanding of modular build
- Stakeholders with limited knowledge of heavy lift and transportation technology available within the global market

MAMMOET

MAMMOET

MODULAR CONSTRUCTION PROJECTS

COLLABORATION

COLLABORATION

- Early involvement is key
- Team work philosophy
- Commitment & trust between parties
- Open approach;
  - Shared values
  - Client's aspirations
  - Project drivers
  - Risks
  - Common objectives

Perform as an integrated team

COLLABORATION

- Supply chain requirements
- Value engineering & optimisation
- Achieved programme certainty and price confidence
- Risks are identified, mitigated wherever possible with the residual risk managed by the best placed party
- Opportunities & innovation realised

MAMMOET

MODULAR CONSTRUCTION PROJECTS

INNOVATION

INNOVATION

- Minimised the need for infrastructure improvements
- Minimised impact on Site operations, the environment and the local community
- Allowed an optimised construction schedule to be realised

INNOVATION

- Heavy lifting services
- Heavy transport services
- Shutdown management
- Site wide construction services
- Modular construction
- Factory-to-foundation/logistics
- Emergency response & wreck removal
- On- and offshore decommissioning

MAMMOET

SUPPLY CHAIN PARTNER

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MAMMOET
THANK YOU FOR YOUR TIME

Presentation slides

for

Federico Perotti

Politecnico di Milano

in conjunction with:

Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

Federico Perotti

Professor at the Department of Civil and Environmental Engineering
Politecnico di Milano

Federico is a Professor at the Department of Civil and Environmental Engineering at the Politecnico di Milano. Previously, he has also been Associate Professor at the Department of Civil Engineering at the University of Brescia. He has taught on programmes including 'Earthquake Engineering Analysis and Design' and 'Theory of Structures for Mechanical Engineering Students', and has been Dean of the School of Civil and Environmental Engineering at the Politecnico di Milano.

His research activity has been mainly in the fields of Structural Dynamics and Earthquake Engineering.

His professional and consulting activity have been focused on applications in Seismic Engineering and vibration problems in Civil Engineering. This includes: seismic analysis of structural and equipment components in nuclear power plants; design input and general criteria for the seismic analysis of the Messina Strait crossing; dynamic analysis of large submerged structures under hydrodynamic and seismic excitation; and structural analysis and design of a number of complex structures such as large turbine generators, printing systems and long span beams/decks under dynamic loading.

ECI Workshop

Improving Modular Construction: Management & Technical Advancements

14 October 2014

POLITECNICO DI MILANO

European Construction Institute

ANIMP

ASSOCIAZIONE NAZIONALE DI IMPIANTISTICA INDUSTRIALE

Structural aspects of modularization

Federico Perotti and Raffaele Ardito

Department of Civil and Environmental Engineering

The White Book on modularization

Is the result of the work of the ANIMP-ECI Task Force "Modularization"

In **Chapter 3** *"Structural design aspects: a case study"* some general considerations are attempted, though based on a single case study performed, at DICA – PoliMi, with the help of MS students (2 MS Theses completed + 1 under development)

A quite comprehensive report of the case study is given in **Appendix B**, while developments of research are treated in the WB **Conclusions**

The White Book on modularization

Aim of the case study: investigate issues related to structural design which affect the feasibility and affordability of modularization

Issues treated in the WB

- on site loading conditions (wind, earthquakes, PSV operation)
- structural design (general + seismic)

Photo from Fagioli

More recent activity

- loads due to marine transportation
- fire design of columns

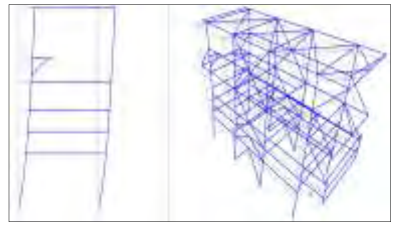
Structural modularization

Photo from Fagioli

Basic CB analysis

"Direct" costs

- Larger structural cost (material/weight, detailing, etc) due to additional loading conditions (transportation, lifting, etc)
- Transportation costs
- Need for larger installation means (cranes, etc)



Basic CB analysis

"Indirect" costs

- More complex structural design
- Need to complete structural design in a shorter time
- Need of early interface with transportation/lifting contractor

Photo from Fagioli

Basic CB analysis

"Direct" benefits

- Reduction in the construction cost
- Reduction of risks associated to onsite construction
- Reduction of project delivery time

Structural modularization

Basic CB analysis

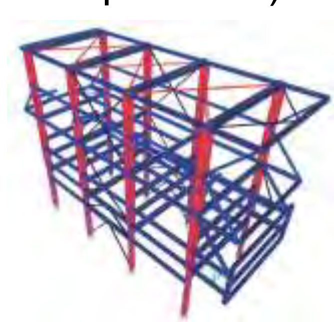
"Indirect" benefits

- Better performance (e.g. in terms of stiffness) of the modularized structure
- Better durability (reducing maintenance)
- Better flexibility with respect to equipment development and/or renovation

White Book: case study

In analyzing the case study (typical pipe rack) some design proposals have been formulated aiming to

- **Reduce weight** (especially at transportation)
- **Introduce some standardization** (versatility?)
- **Improve functionality** (or, at least, preserve)



White Book: case study

Design proposals aiming to

Reduce weight

To reduce the weight of a structure two main areas of intervention can be explored:

(a) classical **structural optimization**, which can be obtained both by varying the structural layout and by working on structural element sizes though preserving the layout. The first option can easily conflict with equipment layout and has been disregarded here. The second has been pursued, even though code provisions have set constraints such to inhibit, in practice, the optimization process.

White Book: case study

Design proposals aiming to

Reduce weight

To reduce the weight of a structure two main areas of intervention can be explored:

(b) **reduction of loads**, which can be obtained either by adopting more sophisticated analysis procedures or by adopting design solutions which are rewarded by the code with a more favorable load level, the latter case being typical of seismic loading; both options have been investigated here.

White Book: case study

Design proposals aiming to

Reduce weight - loads

note that the reduction of loads coming from the equipment (weight, operation and thermal effects) has not been attempted, even though some considerations have been formulated on the loading condition due to the PSV (Pressure Safety Valves) action. Preliminary activity was performed regarding transportation loads, with special reference to standard barges operation, showing that a better insight on loading conditions can be obtained with reasonable effort

White Book: case study

Design proposals aiming to

Introduce standardization

Standardization is the key for addressing the need for a more complex design to be performed in a shorter time; in this light, standardization can be related either to the actual structure or to the design process itself. It can be argued that it is practically impossible to standardize civil structures given the wide spectrum of variable loading combinations that are to be applied according to equipment, seismicity, wind conditions, transportation etc.

White Book: case study

Design proposals aiming to

Introduce standardization

It can be argued that…

In such setting to standardize a structure means to make it easily adaptive to loading conditions of increasing level by simply adding structural elements and/or modifying a limited number of existing ones.

Note: is "versatility" the key word ?

White Book: case study

Design proposals aiming to

Improve functionality

(see "Indirect" benefits list)

•Better performance (e.g. in terms of stiffness) of the modularized structure

•Better durability (reducing maintenance)

•Better flexibility with respect to equipment development and/or renovation

Case study: general issues - stiffness

Note: the pipe rack assembly is constrained almost in the same way on the barge and in its final installation. In spite of this additional stiffening is often provided during transportation

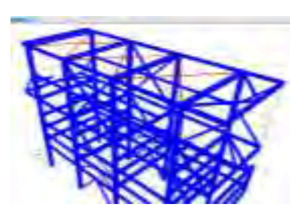
Question: should these stiffeners be introduced in the design, given that loading conditions (i.e. seismic vs barge-roll) are similar ?

Case study: g.i. – horizontal bracing

Question: should these stiffeners be introduced in the design, given that loading conditions (i.e. seismic vs barge-roll) are similar ?

The question *is directly related, for example, to the problem of **horizontal bracing** which, given the results here obtained, should be provided at least at the top level of the pipe rack.*

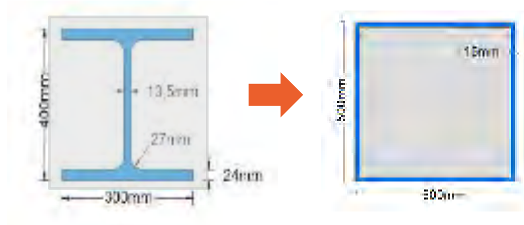
But the issue seems to be a more general one



Case study: general issues – stiffness_2

Note: columns are often encased in r.c. for fireproofing; r.c. is not taken as structural, for equipment development reasons

Proposal: **steel hollow sections, filled with structural r.c**. on site could be used, providing additional stiffness and resistance (and good functionality). Their fire performance, with or without additional protection is investigated



Case study: g.i. – seismic design

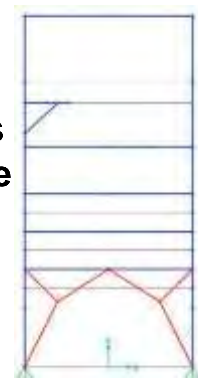
Note: when Ultimate Limit States are considered the problem of structural coefficients (q or behavior factor) is crucial

A *question* arises on how to balance the need for higher coefficients (to reduce load/weight) and the necessity of

1. preserving the (irregular) layout, which affects equipment layout
2. trying to standardize and simplify the structural design

Case study: g.i. – sacrificial elements

Note: *seismic design is often governed by serviceability more than by ultimate behaviour (stiffness again …)*



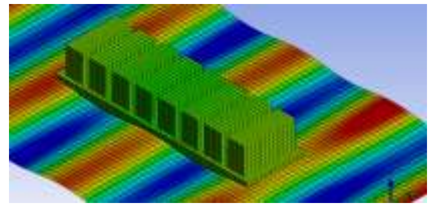
Proposal: introduction of structural elements (typically **diagonal braces) which are accounted for in terms of stiffness** for SLS, but disregarded in ULS checks. They must not obey to provisions for ductile behavior.

Case study: g.i. – welded joints

Note: the possibility, intrinsic to modularization, of extensive use of shop welding pushes towards the use of **welded joints**, which can be lighter and can meet high ductility requirements wrt seismic loads

A question *arises about the possibility of designing* ***standardized welded joints****, with particular reference, to Moment Resisting Frames, typically introduced as transverse frames in pipe racks*

Dynamic loading during sea transportation
(standard barge)



- Use of simple models (linear theory, rigid-body ship model,…) and commercial software
- Evaluation of design sea-state according to route and season

Estimation of dynamic loading on a module and comparison with codes and other loading conditions

Comments

General issues

- Standardization of the structure

  from standardization to versatility

- Interaction between structural and equipment designers

  workflow of the structural and equipment design

- More detailed analysis of loading conditions

  interdisciplinary activity on sea transportation

Future research developments

- A complete non linear analysis of the pipe rack behaviour under strong seismic actions seems to be advisable, also in view of the possible upgrade to a “high ductility” structural systems in light of Eurocode 8.
- A test campaign in the Wind Tunnel seems to be necessary for better calibrating local wind loading and spatial correlation
- *An investigation on structure-equipment interaction (?)*

eci European Construction Institute

Presentation slides

for

Alistair Gibb

Loughborough University

in conjunction with:

Engineering Construction Industry Training Board

Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

Alistair Gibb

ECI Royal Academy of Engineering Professor of Complex Project Management

Alistair is the ECI Royal Academy of Engineering Professor of complex project management and is responsible for knowledge creation and best practice assimilation within and on behalf of ECI across the European organisation.

Alistair is a Chartered Engineer and Chartered Builder. He joined Loughborough University in 1993 following a career in civil engineering and construction management, especially in complex projects.

He has been closely involved with ECI since the mid-1990s, mainly as Project Director of the Safety, Health & Environment task force. Internationally he is coordinator of the Conseil Internationale de Batiment (cib) working commission on construction health & safety. He has led many health and safety research projects funded both by UK and US Governments and industry. He also has an impressive research track record in technical innovation – particularly in offsite construction. He is a founding member of the influential UK industry body Buildoffsite and has led several overseas trade missions.

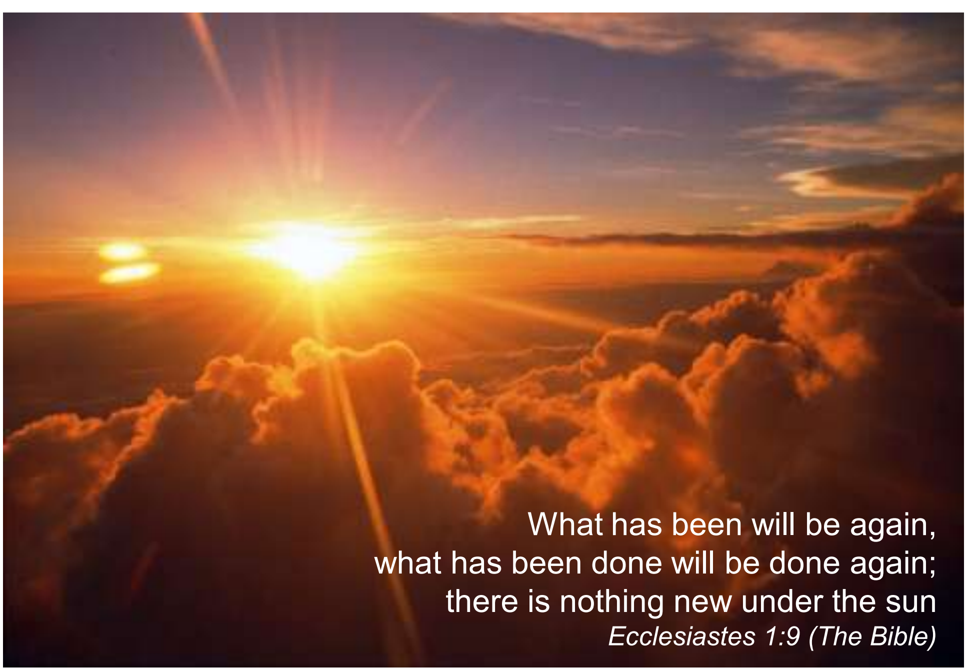
Something new under the sun?

Modularisation in Engineering Construction 2014 Research Update

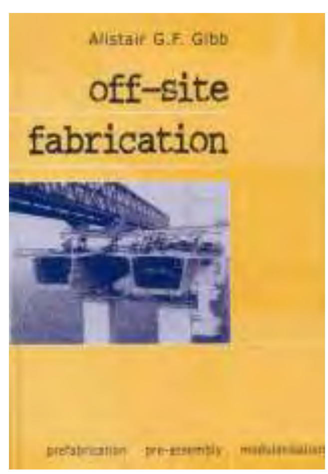
Alistair Gibb

Director: European Construction Institute

Royal Academy of Engineering Professor




There is nothing new under the sun, but there is something old we do not know
~ Laurence J. Peter ~
www.StatusMind.com



buildoffsite

www.offsite-at-lboro.com

Part Two PRINCIPLES

MODULAR CONSTRUCTION & PREFABRICATION for Oil & Gas

Potential Advancements within Industrial Modularization

Alistair Gibb

Director: European Construction Institute

Royal Academy of Engineering Professor

September 2014

European Construction Institute · The Royal Academy of Engineering · Loughborough University

What we do…

- Design as 'stick-build'
- Then decide to 'go modular'

http://slightlywarped.com/ http://i.ehow.com/

Or, we do…

- Decide early to 'go modular'
  - Sometimes for well thought-out, logical reasons
  - Sometimes not
- Then… throw our brains out of the window thinking that modular, by definition, will solve all of our problems

http://static.ilyke.net/

Or, we do…

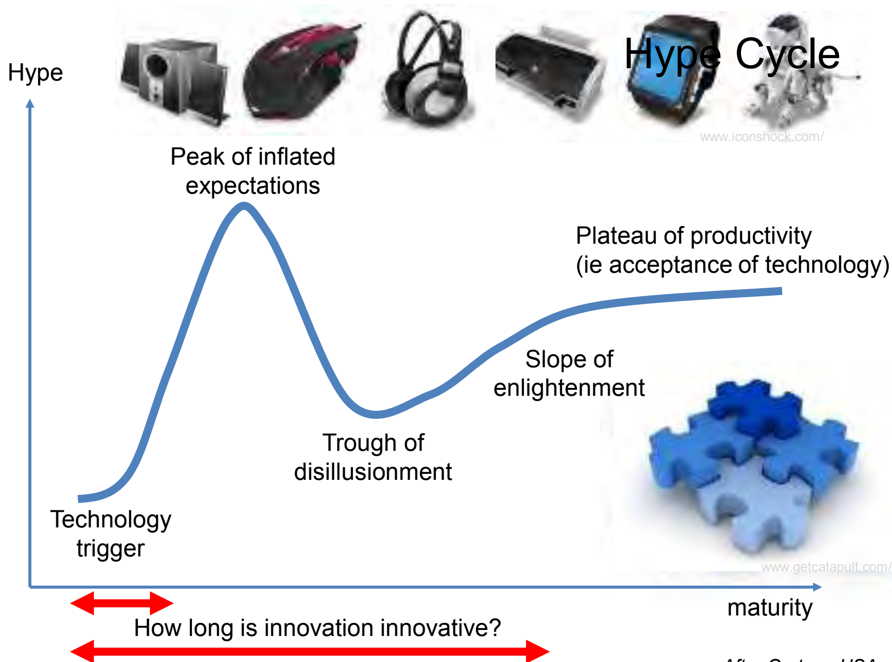
- Decide early to ‘go modular’
- Then… get enticed by the desire to use the biggest module ever used

www.watchismo.com/promotions/bigger-better-banner.jpg


Giorgio Locatelli
University of Lincoln
http://upload.wikimedia.org/
www.richardcyoung.com/

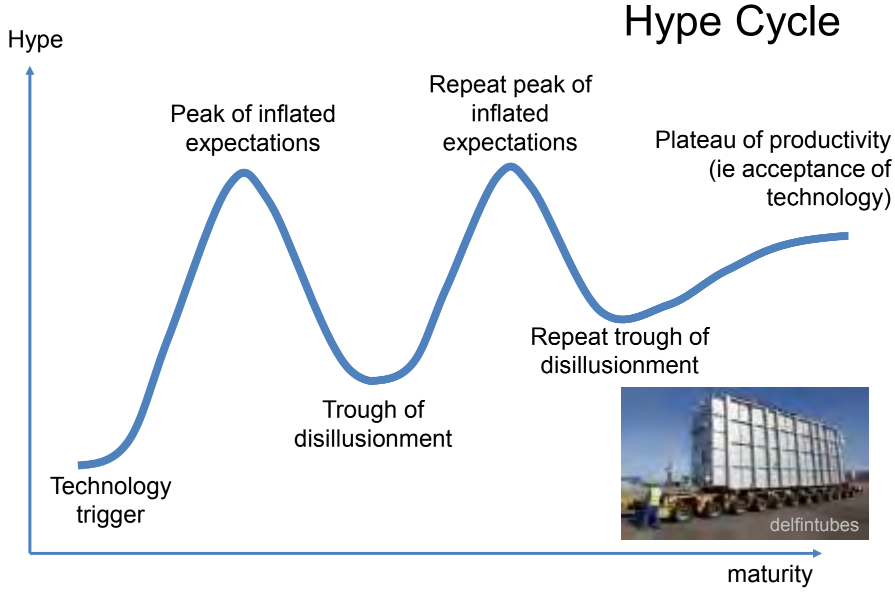

http://sjposters.files.wordpress.com/
Elephant Bird
MAMMOET
THE BIGGEST THING
WE MOVE IS TIME

Hype Cycle



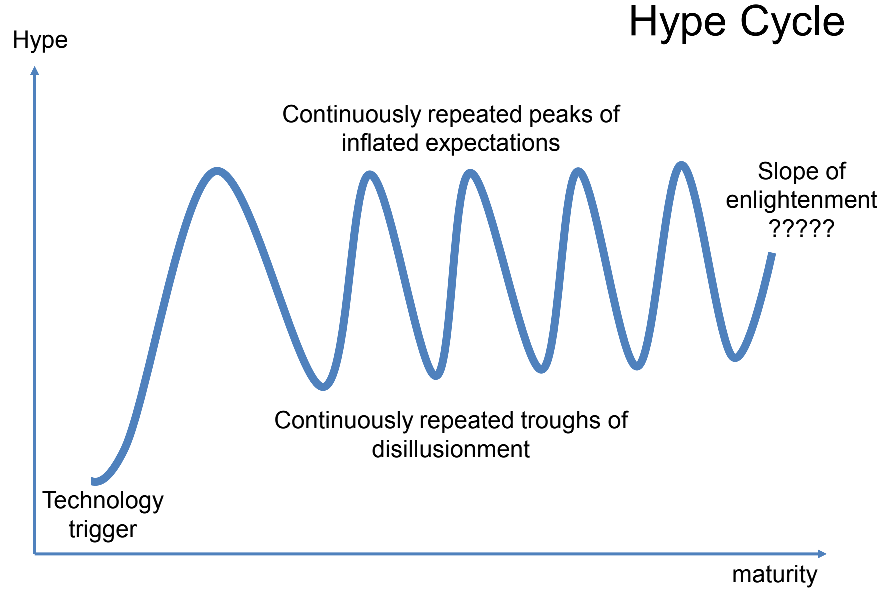
After Gartner, USA

Hype Cycle



Gibb After Gartner, USA

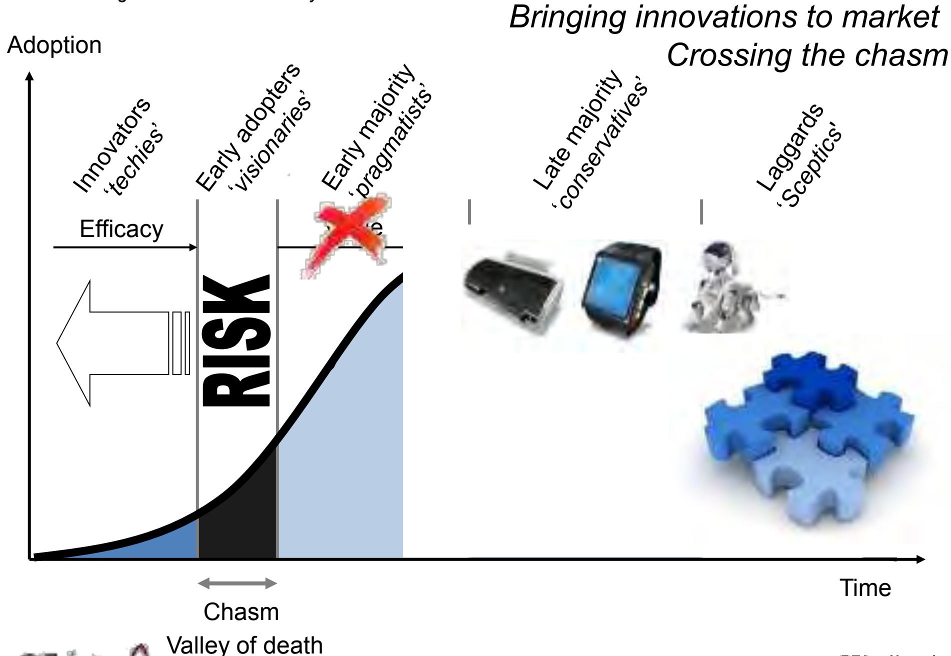
Hype Cycle



Gibb After Gartner, USA

After 'Crossing the Chasm' – Geoffrey A Moore

Bringing innovations to market Crossing the chasm

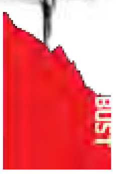


http://grist.files.wordpress.com/

THE COMING BOOM

- Skills shortages
- Investment opportunity
- Early completion
- Expensive labour

- Cheap labour
- Fixed factory costs
- Tight margins
- No long term investment



THE COMING COLLAPSE

http://affordablehousinginstitute.org/ http://matthewashton.files.wordpress.com/

MODULAR CONSTRUCTION & PREFABRICATION for Oil & Gas

15 - 17 September, 2014
Renaissance Amsterdam Hotel,
Amsterdam, The Netherlands

Achieving Project Success Through Modular Construction

Mauro Mancini
Politecnico di Milano, MIP
Chairman of ANIMP Construction Section
(Italy)

ASSOCIAZIONE NAZIONALE DI IMPIANTISTICA INDUSTRIALE

http://animp.it/prodotti_editoriali/Advances_in%20plant_modularisation.php?codice=AB57842

Skip Background

Mechanism	Phonebloks	Modular LNG
Modules design	x	x
Modules standardisation	x	
Interfaces design	x	x
System physical decomposition	x	
System functional decoupling	x	
Platform design		
Bus architectures	x	
Modules Sharing		x
Modules swapping	x	
Minimise inter-module interactions	x	
Aggregation into cell modules		
Modular consortium		x
Sectional modularity		x
Interfaces Standardisation	x	
Design for Postponement	x	

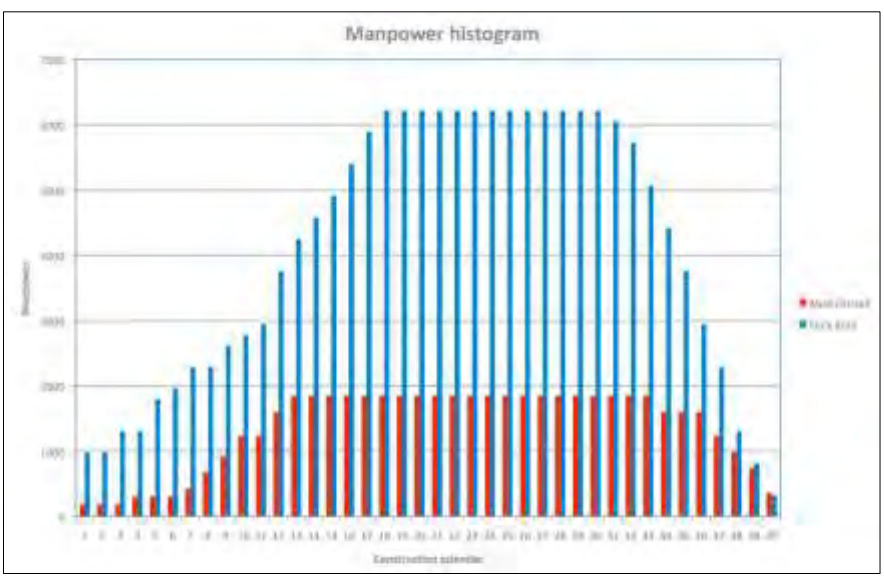
Do we already reach the full potential of a modular approach?

Main Characteristics of Plant Modularization

Transfer as much of construction site works as possible to a more controlled and favorable environment, i.e. fabrication yards.

Profound effect on the way the engineering work is defined and scheduled

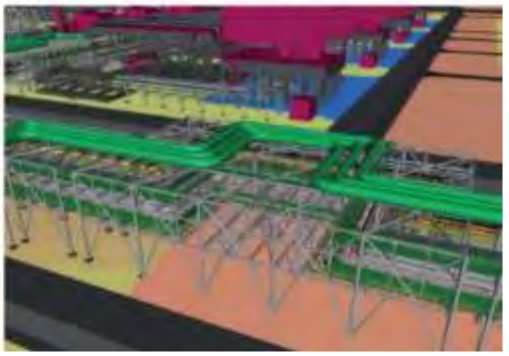
Need of progressive fundamental decisions at the early FEED (that cannot be significantly changed into an EPC Company)



(On site?) construction workload: modular vs stick build SAIPEM 2013

Taxonomy in Plant Modularization

PAU 3D Model Detail PAR with expansion loop 3D Model Detail



Taxonomy in Plant Modularization

Self-Propelled Modular Trailer

Taxonomy in Plant Modularization

Load in of a module in detail

Taxonomy in Plant Modularization

Load out of a module in detail

Load out of a 2000 ton living module

Modularisation benefits	
Schedule Savings	Higher Safety
Improved quality	Higher Security
Social/Environmental Impacts reduction	Lower Manpower costs
Reduction of weather impacts	

Modularisation drawbacks	
Higher engineering effort	Higher structural costs
Higher transportation costs	Higher need for infrastructure
Local content impacts	...

Literature

COMAPNIES INVOLVED	ROLES INTERVIEWED	NUMBERS OF INTERVIEWS
eni, Tecnimont, saipem	Engineering	
TECHINT	Procurement	
Technip	Construction	
ROSETTI MARINO Group of Companies	Tendering	
FAGIOLI, FOSTER WHEELER	Project management	

COMPANIES INVOLVED		
CLIENT	EPC	SERVICE PROVIDER
bp, BG GROUP, Sellafield Ltd, gsk, Shell	amec, MORGAN SINDALL, FLUOR, HOME INTERNATIONAL	MAMMOET, GROUPCYTEK

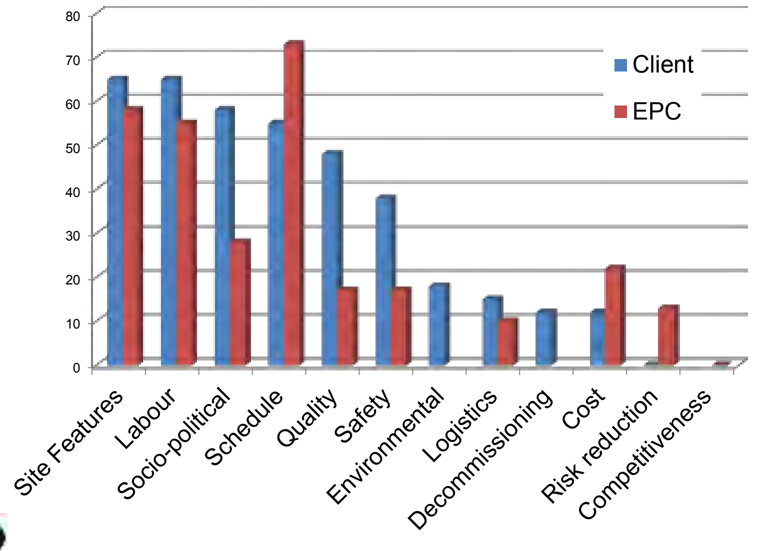
Matteo
Apicella

Head of Project Management
Project Development Director
Principal Project Manager
Project Advisor
Project Development Manager
Chief of Civil Engineering
Responsible Engineer
Project Manager
Construction Engineer
Director, Process & Engineering
Operations Director
Technical Sales
Managing Director
Sales Manager
Senior Project Engineer
Senior Principal Engineer
Design and Engineering Manager

COMPANIES INVOLVED		
CLIENT	EPC	SERVICE PROVIDER
bp, BG GROUP, Sellafield Ltd, gsk, Shell	amec, MORGAN SINDALL, FLUOR, HOME INTERNATIONAL	MAMMOET, GROUPCYTEK

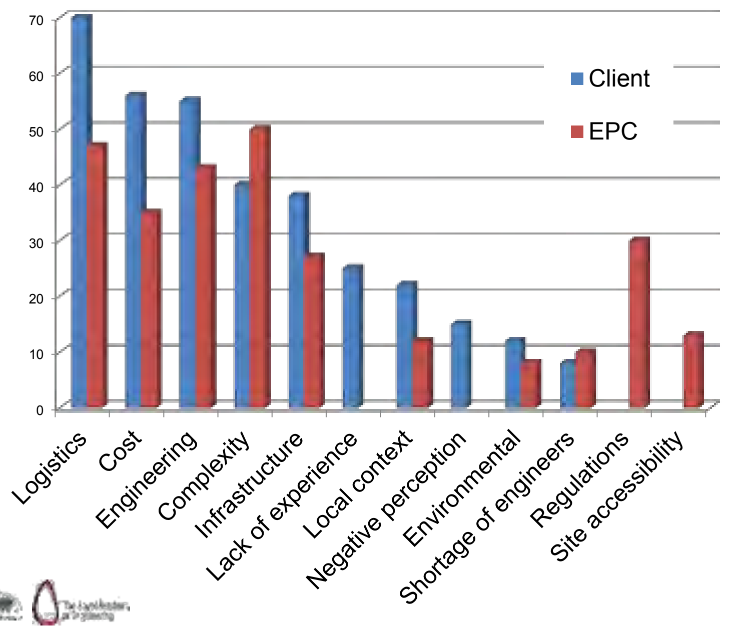
Drivers (Client vs EPC)

Open-ended question – suggested items then scored 1-100

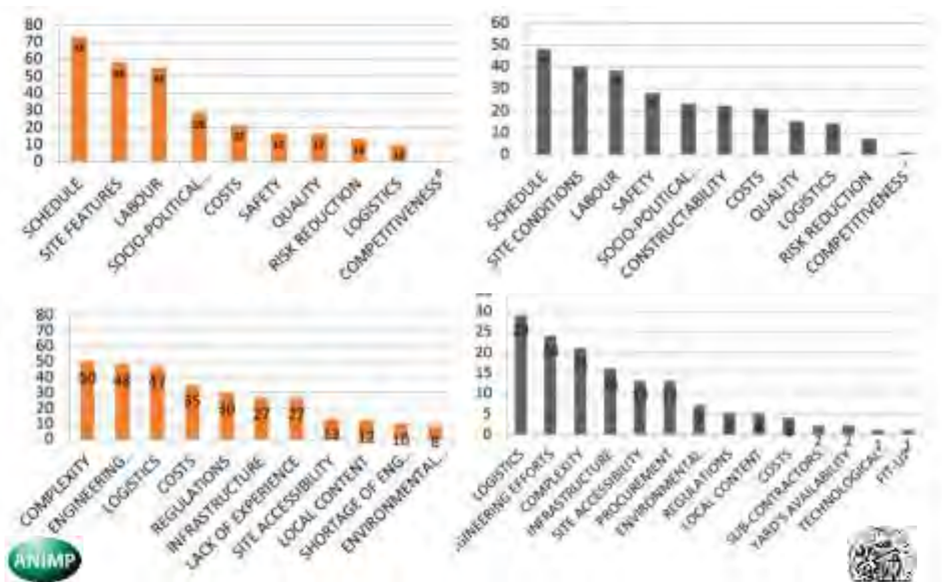


Constraints (Client vs EPC)

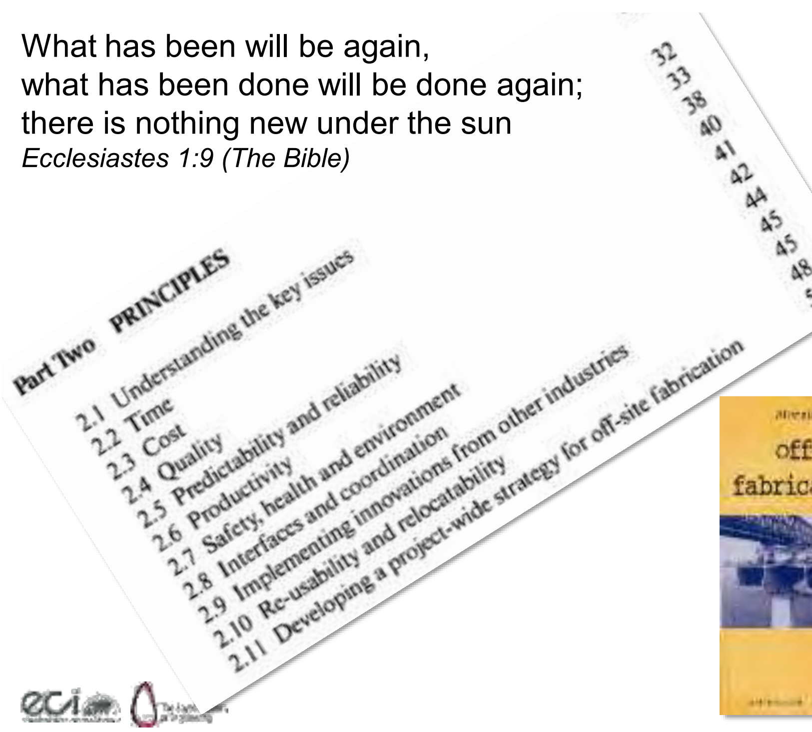
Open-ended question – suggested items then scored 1-100



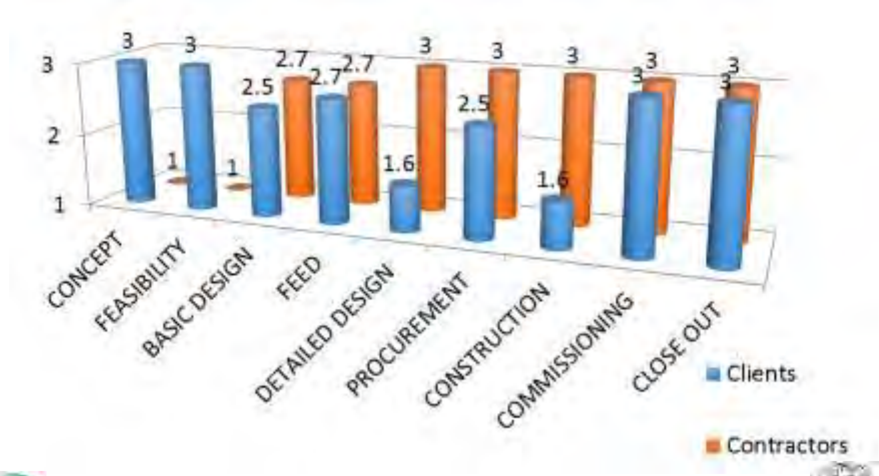
Drivers & Constraints (UK-EPC vs Italian-EPC)



What has been will be again,
what has been done will be done again;
there is nothing new under the sun
Ecclesiastes 1:9 (The Bible)


Part Two PRINCIPLES

Involvement in project life cycle (Clients vs EPC)



SKIP CII

Five solution elements for increasing the use of modularization on industrial projects:

Construction Industry Institute®
Decision Support

1. business case process
2. execution plan differences
3. critical success factors (CSFs)
4. standardization strategy
5. modularization maximization enablers

Addresses the following modularization issues:

- assessment of benefits and costs of the modular approach;
- determination of the optimal level of modularization on a project;
- methods and timing of modular implementation;
- isolation of the CSFs that drive modular success;
- use of standardized modules versus the modular standardized plant
- strategies for overcoming industry-wide barriers to higher levels of modularization.

CII IR283-2 2014

The challenge…

Something new under the sun?

Modularisation in Engineering Construction
2014 Research Update

http://animp.it/prodotti_editoriali/Advances_in%20plant_modularisation.php?codice=AB57842

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