Title Modular Construction vs Traditional Construction, a Total Cost of Ownership Comparison of Data Centre Construction [1]

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ABSTRACT

In 2019 the value of modular data centre was valued at USD 17.67 billion[2] with a 2025 market value expected at USD 72.53 billion. The trend of the market is pushing to reduced deployment time, driven by the significant increase of digital data and 5G technology

As more and more organization are now passing or adopting more cloud-based solutions, the construction of data centres is experiencing a steady growth around the world driving the ever-present discussion, within the data centre construction world, of traditional construction data centres against modular data centres. Especially when the discussion touches the cost argument disagreement arises on the potential cost advantages and scalability advantages of modular data centres against traditional data centres.

Key Words: Data Centre, Modular Data Centre, Total Cost of Ownership, Digital engineering, Modular Construction, Traditional Construction, Customization, Process

INTRODUCTION

In late 2011, a 328-foot-tall or 99 meters, 30 story tower called the T30 appeared in China's Hunan Province, almost from nowhere, and was built in just 15 days at a fraction of the typical construction cost! The actual construction video is impressive to look at:

www.youtube.com/watch?v=8UQDn5bKrGQ

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[2] Modular data centre market | Growth, trends, and forecasts (2020-2025). (n.d.). Mordor Intelligence. https://www.mordorintelligence.com/industry-reports/modular-data-centre-market

Fig.01: Completed T30 building in Huna Province, China[3]

But how did they manage to do it? The answer is simple, with modular construction.

"Modular construction is a process in which a building is constructed off-site, under controlled plant conditions, using the same materials and designing to the same codes and standards as conventionally built facilities – but in a reduced time. Buildings are produced in "modules" that when put together on-site, reflect the identical design intent and specifications of the most sophisticated site-built facility – without compromise."[4]

[3] T30 hotel - The skyscraper centre. (n.d.). The Skyscraper Centre. Https://www.skyscrapercentre.com/building/t30/14432

[4] What is modular construction? | Modular building institute. (n.d.). Modular Building Institute. https://www.modular.org/HtmlPage.aspx?name=why_modular

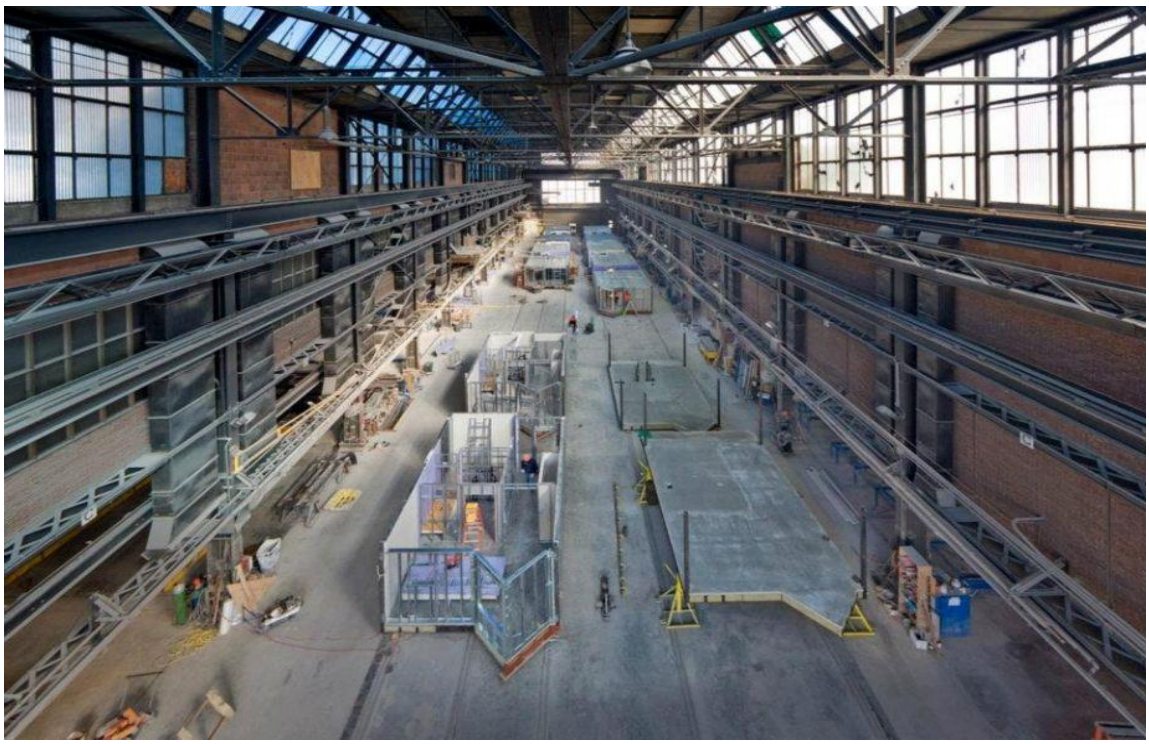

Fig.02: Housing modules under assembly[5]

"While the construction industry is slow in evolving and adopting efficiencies, the construction industry is experiencing further industrialization driven by a shift towards off-site construction and a growing interest in mass-customization, as we have seen during the current Covid-19 pandemic with hospitals built in a matter of days."[6]

On-time communication and collaboration are one of the essential components for the success of a project. The problem is that, due to the complexity of the numerous tasks, there are many cases where stakeholders in construction are battling against low productivity, high rework rates and costly delays. The good news is that with the rise of digital technologies, modularisation has started to change things for the better.

If we want to achieve a improve the industrial shift in construction, we need two main characteristics.

1. The construction sector must increase its manufacturing and automation capabilities
2. The construction sector needs to establish efficient, effective, and flexible production systems that can adapt to ever-present changing requirement conditions imposed by

[5] The bumpy road for modular construction in NYC. (n.d.). Next City – Inspiring Equitable Cities. https://nextcity.org/daily/entry/the-bumpy-road-for-modular-construction-in-nyc

[6] A closer look at the Chinese hospitals built to control the COVID-19 pandemic. (2020, April 15). ArchDaily. https://www.archdaily.com/937579/a-closer-look-at-the-chinese-hospitals-built-to-control-the-covid-19-pandemic

clients, technological development, business considerations and other corporate reasons.

To try and resolve this challenge, the construction sector is establishing modularisation strategies. "Modularisation allows for the clustering of different product sub-systems or components into modules to increase the flexibility of the overall production system."[7]

Modularisation allows for quicker and easier re-configuration of the products to meet the demands, even if customized, without altering in a significant way the original product or the production of the product.

In the construction sector, research, and application to achieve greater efficiency have been slow to be implemented. We need further studies in the construction industry to evaluate how to control product changes and accomplish efficiency in cost. Even if there are multiple modularisation tools, there is a challenge to determine useful tools for supporting efficient developments of modular products in construction.

But the recent resurgence of modular construction appears to be here to stay. Major developers are creating their own specific manufacturing arms for modular construction, see Berkeley Homes in the Uk being an example of this with the emergence of Berkeley Modular[8]. Investments in the modular construction have also increased significantly as per below graph:

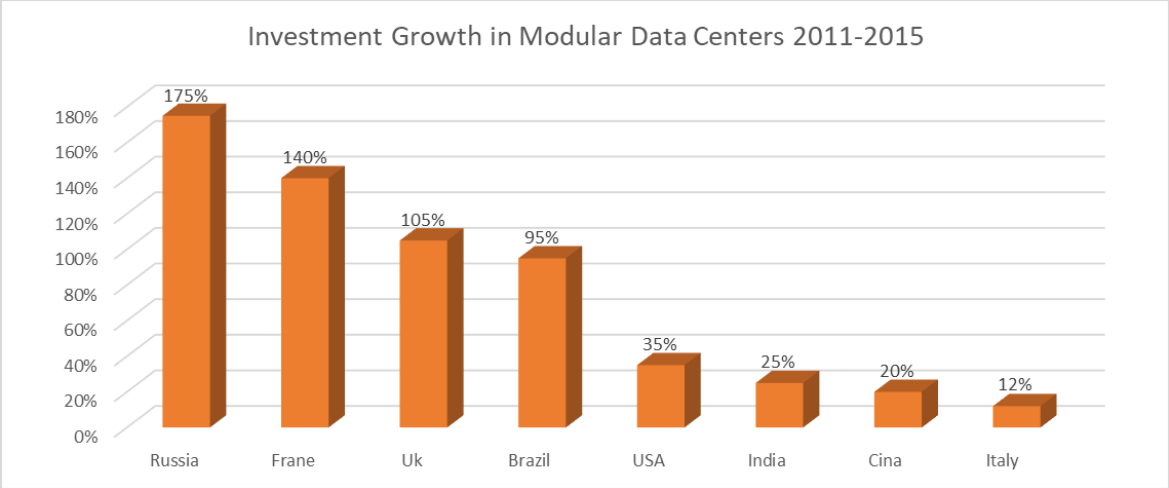

Fig.03: Investment growth of modular data centres[9], graph produced by the author

[7] Borjesson, F., & Hölttä-Otto, K. A., (2014). A module generation algorithm for product architecture based on component interactions and strategic drivers, Research in Engineering Design, Vol. 25 No.1, pp.31-51. https://doi.org/10.1007/s00163-013-0164-2

[8] Berkeley modular. (n.d.). Berkeley Group. https://www.berkeleygroup.co.uk/about-us/our-brands/berkeley-modular

[9] Modular data centre market next big thing | Major giants HP, Dell, IBM, Huawei. (2020, July 27). Market Research Posts. https://marketresearchposts.com/2020/07/27/modular-data-centre-market-next-big-thing-major-giants-hp-dell-ibm-huawei/

Many elements will impact the cost of deploying a data centre, both modular or traditional, including each specific requirement and location, like dimension, geographical location, the type we can define four different drivers/categories subdivided by the direct and indirect cost that can be considered for all, these include the following;

1. Planning & Preparation:
2. Deployment
3. Operation
4. Decommissioning

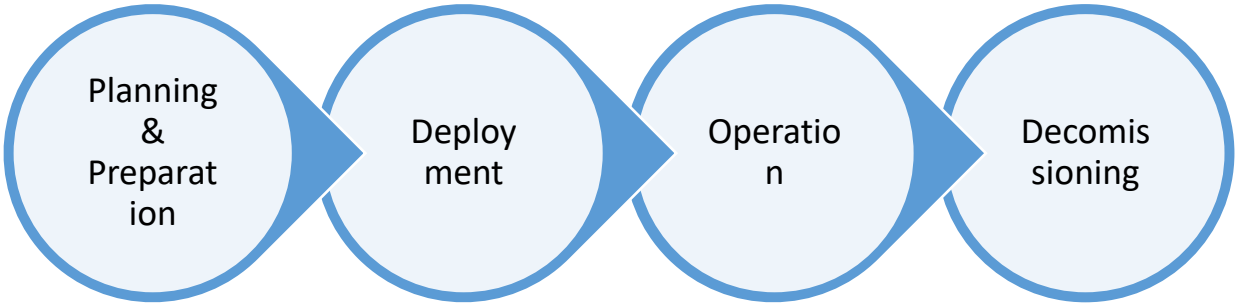

Fig.04: Typical Data centre Lifecycle, by author[10]

The division between direct and indirect cost can also be considered for cost-saving opportunities of the two methods.

Direct costs are those that arise because from design, procurement and deploying of the modular equipment and all preliminary works to prepare the chosen site for a new installation. Many costs form part of the direct costs group, including site design costs, cost of the land, permits, shipping or other, but they also include staffing, energy, maintenance and other costs associated to the day-to-day operations of a Data Centre.

By contrast, indirect costs include those that arise as an indirect consequence of specific deployment and operating choices. Indirect costs include those that arise due to a longer time to market with a new deployment. We can say that the longer we need to wait to have a new facility operating, the more probable it will have cost due to loss of business, or because we have an inefficient facility. On the other side, a shorter time to market will allow organizations or operator to have early financial benefits. We also need to consider, for indirect costs, events that cannot be preventive, even including downtime periods of the data centre. Off course, this indirect cost could arise for both types of deployment.

[10] Typical Data Centre Lifecycle, by author

Why are we seeing such a great level of interest from major organizations? While an overall market request is driving the market request, the possibility of mobility and scalability is driving the modular data centre market, scalability in one of the top challenges faced[11].

Can we objectively say that a modular approach is better than the traditional one or vice versa comparing from the point of the total cost of ownership for a data centre?

We can identify four main cost categories that are relevant to the deployment and operation of data centres:

1. Planning & Designing
2. Deployment
3. Operation
4. Decommissioning and redeployment

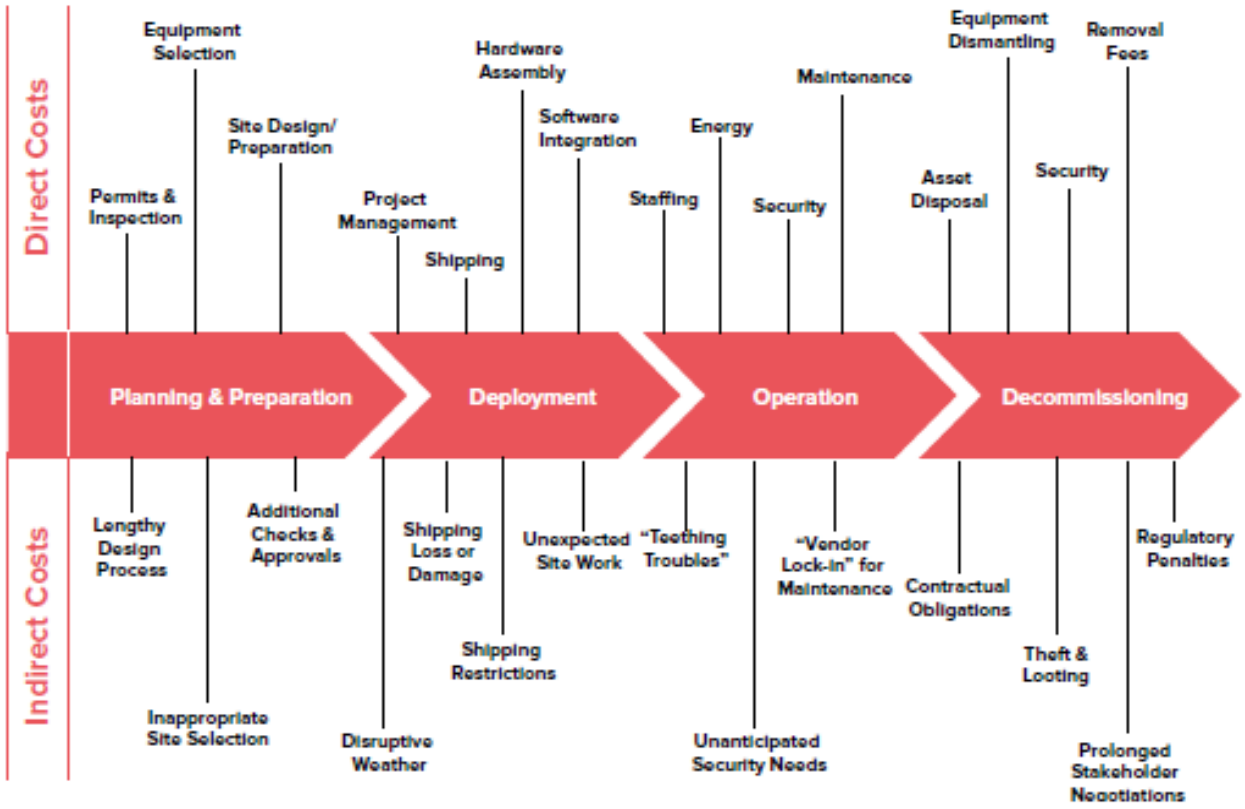

Fig.05: Cost Categories for the Data Centre Lifecycle[12]

[11] Modular data centre market | Growth, trends, and forecasts (2020-2025). (n.d.). Mordor Intelligence. https://www.mordorintelligence.com/industry-reports/modular-data-centre-market

[12] Cost Categories for the Data Centre Lifecycle, by author

METHODOLOGY

Step 1

It is commonly assumed that having the possibility to support operators and organizations reduce the cost to be one of the main benefits and attraction to the modular data centre. But, although we will see that modular data centre can offer significant reduction of costs in many areas, it would be extremely simplistic to say that modular data centres have lower costs, in particular when we want to consider the Total Cost of Ownership.

As we will see in this technical paper, many costs are present both in the modular data centre construction as well as in the traditional data centre construction. Some costs are clearly associated with both types of deployment;

- Site selection and preparation costs
- Procure land and obtain permits
- Planning permissions

Not to forget also those costs related to powering, securing, and decommissioning of the data centre when it will approach the final stages of its life.

Modular data centre deployments, while sharing the cost with traditional built approaches, has its specific sets of hidden costs that could include additional permits, see if authorities consider the modular data centre as different pieces of equipment instead of a building could ask for additional safety checks and further approvals that might not be necessary for a traditional building.

Moreover, when examining the motives which organizations say to be behind their decision to choose the modular solution, it becomes evident that the potential cost saving is just part of the factors that have a say in the deployment decision.

Other important factors for data centre operators investing in modular technology include the speed of deployment and the increased energy and operational performance.

Increased performance over traditional data centres can be achieved thanks to the optimized and standardized design that is used for modular solutions as we can have a greater built-in design specification that ensures that modules have a more efficient cooling and in consequence lower power consumption.

Many organizations say that increased efficiency in energy management and improved PUEs[13] to be one of the biggest, if not the biggest, driver and motivator for a decision to go for a solution that is the modular data centre. While greater energy efficiency is not as reducing energy costs

[13] PUE calculator. (2020, June 4). 42U. https://www.42u.com/measurement/pue-dcie.htm

if we can achieve greater use of the energy, we should be able to have reduced energy bills that do not rise at the same level as energy consumption.

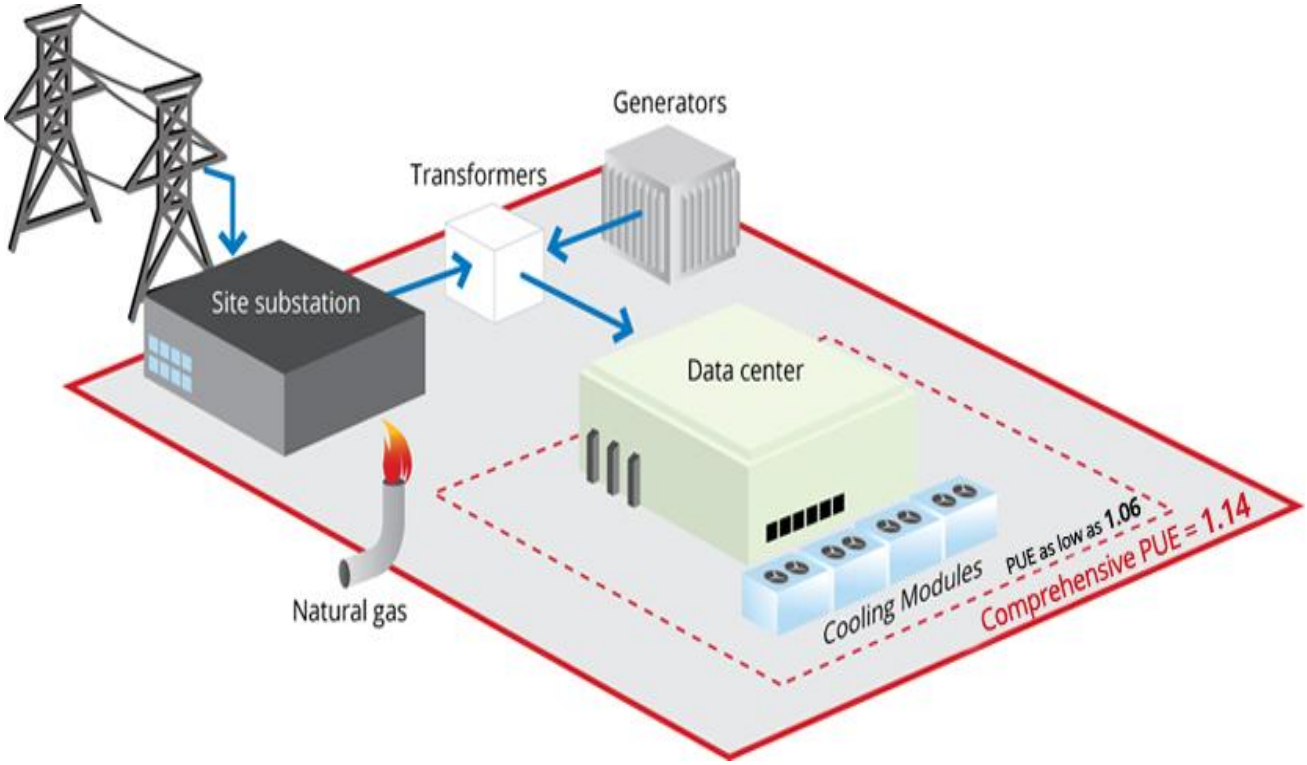

Fig.06: Measuring to improve PUE[14]

Onward with greater energy efficiency, the standardization of the design for the modules of the facility allows operators of data centres various additional improvements. In particular, these allow for reduced complexity (making modules easier to deploy, maintain and decommission) and improved reliability, with standardized and factory-tested modules that offer operators greater chances to estimate how the data centre and overall business will perform. Not only, but vendors can also assert that using a standardized, repeatable solution for the owners and operator of data centres will allow to scale or reduce their operations quicker and with reduced issues.

With modules, we have an increase in mobility as a key attraction for the modular data centre over traditional data centres. Even if containerized solutions will offer the most significant degree for a mobile data centre, as this makes modular solutions for operations and organizations to evaluate the relocation of their data centre operation to a different date.

[14] Measuring to improve: Comprehensive, real-world data center efficiency numbers. (2012, March 26). Official Google Blog. https://googleblog.blogspot.com/2012/03/measuring-to-improve-comprehensive-real.html

As a final point, we need to consider that, although some of the key attractions of a modular solution do not have cost as a primary point, in part some of them have significant cost implications for each data centre operator. As a general example, operators and organizations that want to deploy modular data centre solutions often refer to the shorter time to market as a critical point to go modular data centre.

The same point can be made between direct and indirect costs and direct and indirect cost savings. It is quite clear that If an organization has to wait longer times for the centre to be operating, the more probable it will be to generate costs due to lost business, or also operators and organizations has a less efficient facility. This means that a shorter time to reach the market will allow organizations and operators to have financial benefits with a sooner to the market facility.

Step 2

As we have discussed before we have defined our feasible alternatives as follows:

1. Modular Construction of Data Centres
2. Traditional or Stick Built Data Centres

And we will review our viable options based on the following criteria:

1. Planning & Preparation Costs
    a. Data centre design
    b. Site Selection and Preparation
    c. Planning Permissions and Permits
2. Deployment Costs
    a. Installation Costs
        i. Shipping
        ii. Hardware Assembly
        iii. Software Integration
        iv. Project Management
        v. Commissioning
        vi. Cost Predictability
        vii. Upfront vs Deferred Cost
3. Operational Costs
    a. Energy Expenditure
    b. Maintenance
    c. Staffing
    d. Security
    e. Balance Sheet Considerations
4. Decommissioning and Redeployment Costs
    a. Decommissioning
    b. Redeployment

Step 3

Based on the previously established attributes we can now compare each of the criteria between the two different solutions, modular and traditional construction

1. **Planning & Preparation Costs (% of total costs)**

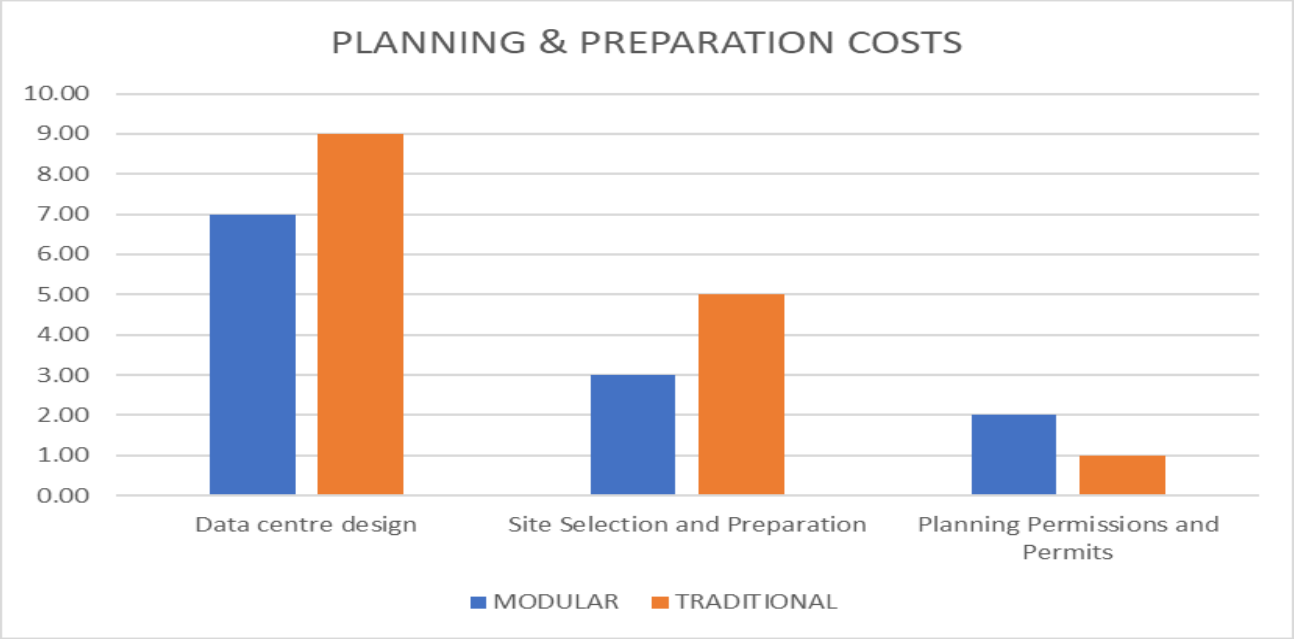

Fig.07: Planning & Preparation Cost Breakdowns[15]

Many operators or end-user of data centres refer to “cost predictability" as probably the most significant appeal to switch from traditional data centres to modular data centres. Having a more considerable control or more precise estimate, in particular to the standardized, repeatable design of the different modules and also we can have the modules mostly preassembled, integration and pre-commissioning included in the final cost. This allows the company’s and other organizations to estimate the costs of expansions and first-time deployment with greater accuracy.

Verne Global[16] , a modular end-user, identifies CAPEX[17] predictability as a critical driver for embracing modular solutions. Also, other modular end users agree and refer that the modular model allows for greater control over operational costs.

[15] Planning & Preparation Cost Breakdowns, by author

[16] (n.d.). Verne Global, Leaders in Sustainable HPC. https://verneglobal.com/

[17] Guild of project controls compendium and reference (Car). (n.d.). Planning Planet | dedicated to Project Controls. https://www.planningplanet.com/guild/gpccar/introduction-to-managing-cost-estimating-budgeting

End users and vendors refer to greater cost control and predictability, about the benefit of deferred costs as the main attraction of modular deployments.

We can say that deferred costs[18] refer to the timing of CAPEX allocation, as we can see, a data centre is a significant capital expense that requires considerable upfront costs. While in traditional construction, organization have to prepare for the almost secure growth in their requirements of the IT infrastructure, even up to ten years or more in the future. In reality is that the pace of technological evolutions makes this almost impossible to estimate or predict and, because of this, quite a few traditional data centres are actually constructed with sufficient overcapacity to allow for probable future requirement.

This makes facilities more expensive to operate, leading to higher costs to built. Contrary to this, modular construction have the possibility to be deployed quicker and respond faster to the request of additional IT resources, thus reducing the capital that we would have to use upfront.

As a result we could say, rather than allocating US$50 million upfront to develop a new data centre project, organizations can choose to purchase ten US$5 million modules as their requirements grow in time.

Deploying a modular solution, however, means that organizations and operators would need to spend 15% of the total expense to be able to cover the first 10% of the project. Additionally to requiring a much larger share of total project costs to be spent upfront, many times it said that, when considering approached of traditional build, we need to allocate capital at in an earlier stage of the deployment of the centre.

Capital needs, in some cases, to be allocated even two years prior to the data centre id actually operational and even before any return on the investment can be achieved.

[18] Deferred cost — AccountingTools. (2019, December 21). AccountingTools. https://www.accountingtools.com/articles/what-is-a-deferred-cost.html#:~:text=%20Other%20examples%20of%20deferred%20costs%20are%3A

3. Deployment Costs

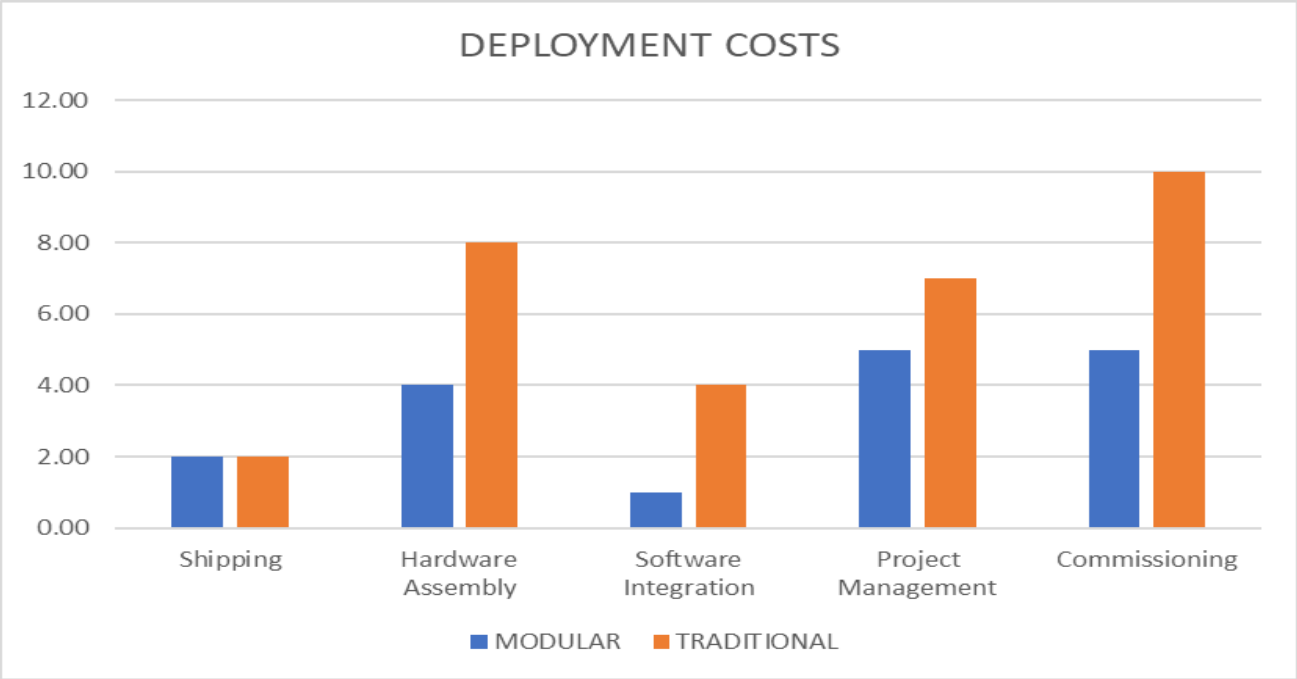

Fig.08: Deployment Cost Breakdown[19]

4. Operational Costs

While security cost can be considered as having the same weight in the operational costs, some cost items in the modular solution require less staff, so potentially less cost, and in particular reduced maintenance cost for the modular solution compared to the traditional solution. This because the pre-engineered and pre-integrated solution of modules that we will have a responsible or provider that is responsible.

This makes it easier for operators to identify who is responsible for the maintenance of specific issues.

[19] Deployment Cost Breakdowns, by author

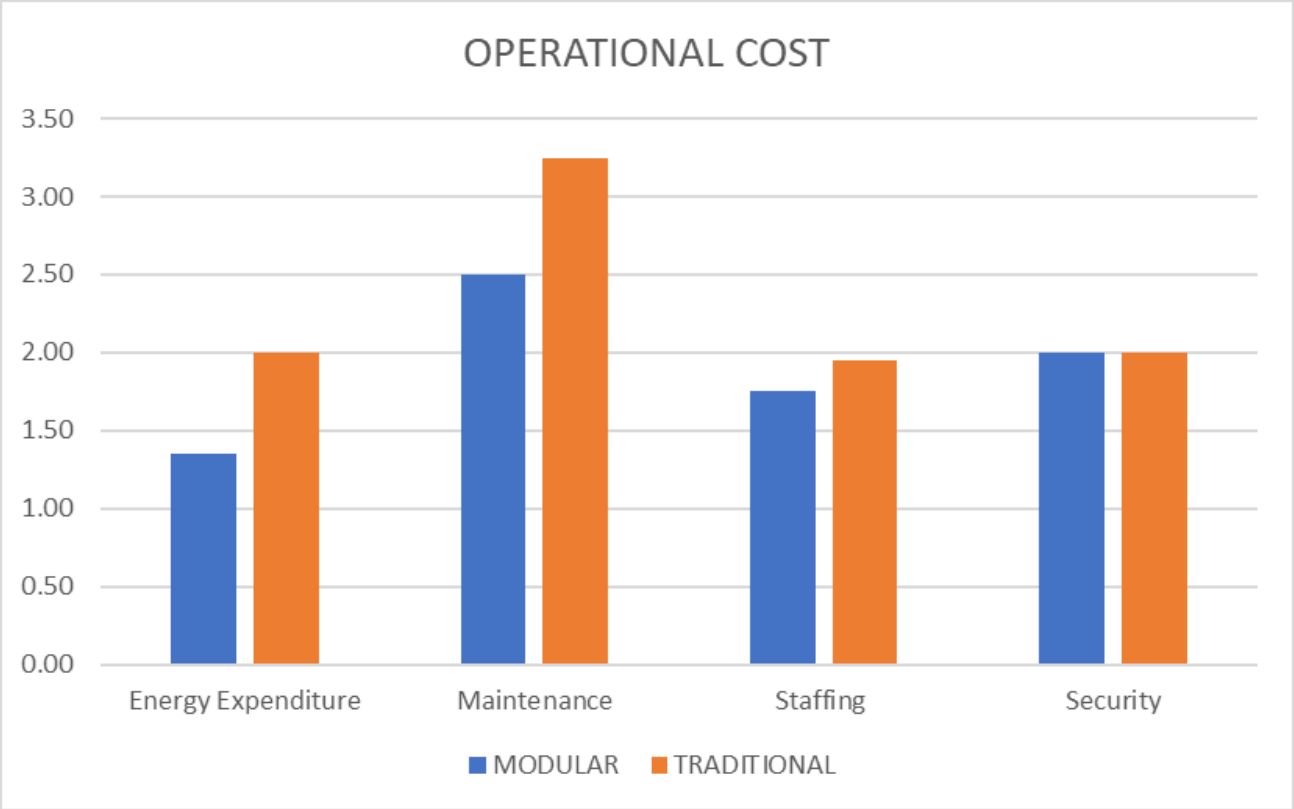

Fig.09: Operational Cost Breakdown[20]

We should also consider, although taking in different consideration regulations in other countries, that we could consider data centre prefabricated modules as equipment or temporary instead of a building, this would have significant implications on the operator of the data centre balance sheet because it could influence which modules[21].

Generally, we consider cooling and power equipment to be part of the data centre building; thus, it has to be depreciated usually in a period of 30 or more years. But if we can classify a data centre module as a piece of equipment instead of a building, then it should be possible to depreciate in a shorter time-frame, even in 5 to 15 years, giving a great advantage, compared to the 30 or more years of the traditional data centre.

We should also take into consideration the reduced depreciation times that brings positive ramifications for the operator/company tax structure. As the depreciation is taken from an operator/company's profits before we can calculate the income tax, if we are able to discount

[20] Operational Cost Breakdowns, by author

[21] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). Chapter 7, Depreciation, and Income Taxes. Engineering economy.

an item as necessary as a data centre module has most probably a great implication for an operator/company's cash flow[22].

5. Decommissioning & Redeployment

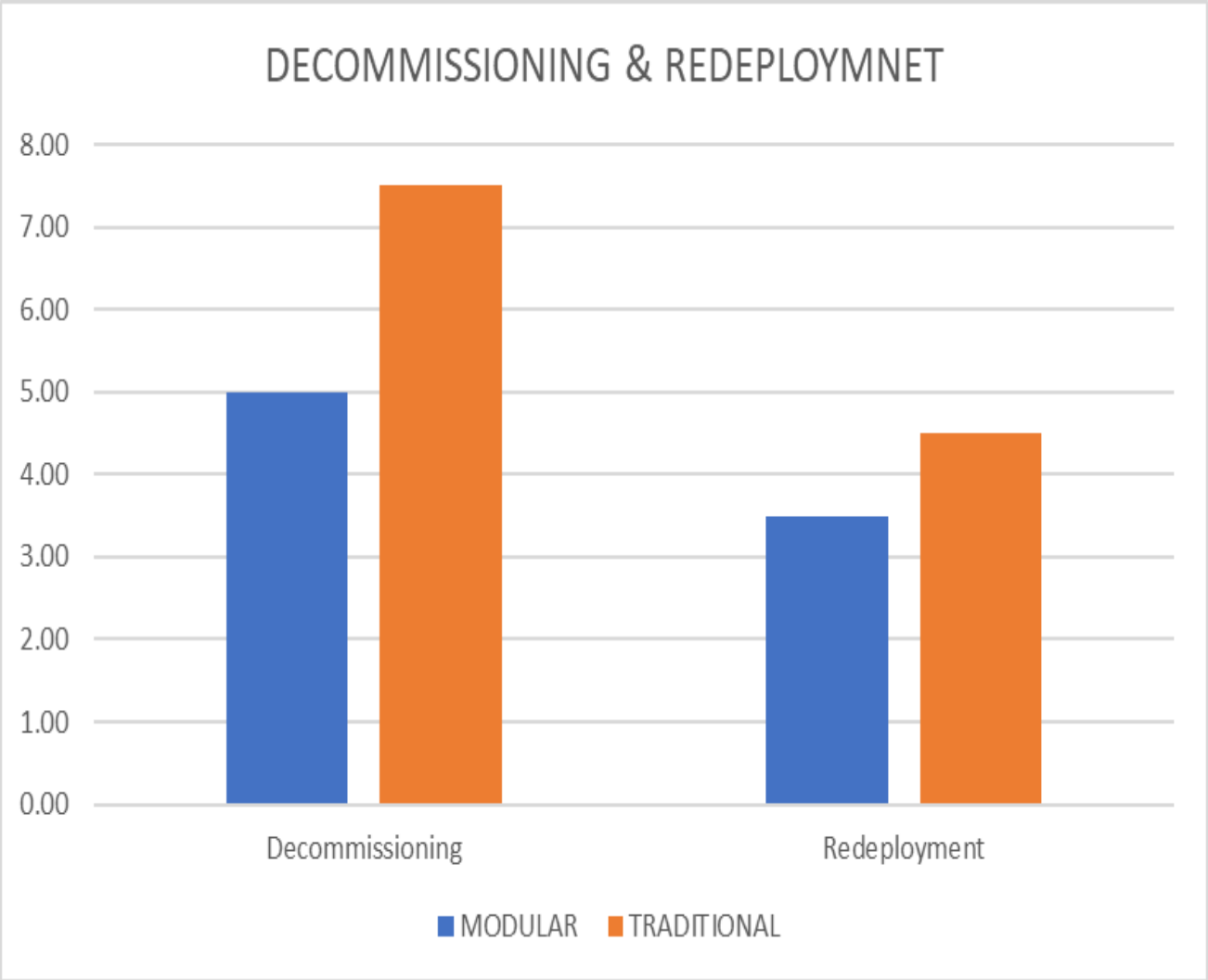

Fig.10: Decommissioning & Redeployment Costs[23]

Step 4

Now we have reviewed all solutions from our assumptions, both for the traditional data centre and modular, and which has the greatest and least impact, and what uncertainties we have due to the amount of data available. This will allow us to properly understand which are the answers to our technical paper's questions.

[22] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). Chapter 4. The time value of money. Engineering economy.

[23] Decommissioning & Redeployment Costs, by Author

FINDINGS- 500 to 1500

Step 5

Even if the access to data is limited, we managed to draw a conclusion based on our direct experience, as we can see from fig.11 we could obtain a saving of up to 35% lower with the modular solution, this reflects the preassembled and pre-integrated nature of the modular equipment.

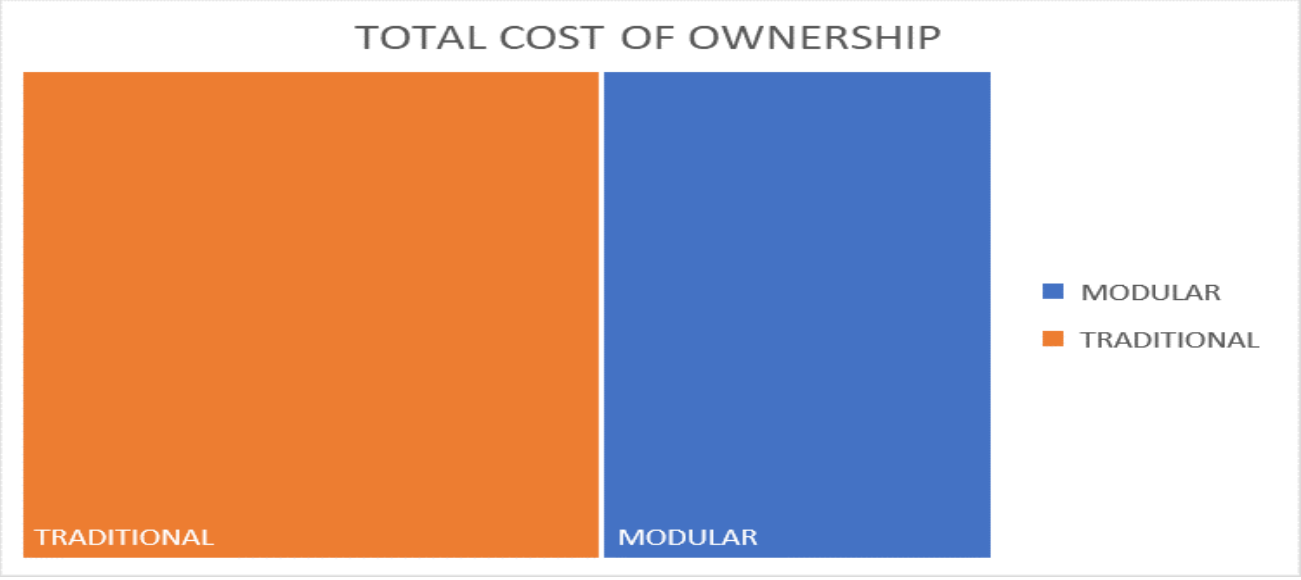

Fig.11: Total Cost of Ownership

CONCLUSIONS

A growing passion among operators for modular technology can be seen in the modular technology, because of the possibility of achieving cost savings for operators.

While modular solutions offer potentially compelling savings in cost in different areas, we cannot say that that modular construction will always give data centre operators significantly lower prices. As a starting point, it is fundamental to recognize that there is an always-increasing number of products of the data centre in the market, that have different certifications, standards and support to the end-user.

Although the limited availability of data, we can draw a series of conclusions to compare the two different type of deployment of similar capacity, including recently tested underwater datacenters from Microsoft[24].

[24] Microsoft finds underwater datacenters are reliable, practical and use energy sustainably. (2020, September 16). Innovation Stories. https://news.microsoft.com/innovation-stories/project-natick-underwater-datacenter/

One of the findings is:

- 40% higher cost in modular construction for hardware and software, due to pre-assembly and pre-integrated of modular equipment, which compensated by
- 60% lower costs in on-site installation

With this, it is clear that with modular construction, we can achieve this with easier on-site installation and shorter installation times, thus requiring fewer resources.

As we have seen from the previous data and assumptions, we can say that we can achieve a 13% to 18% reduction of Total Cost of Ownership when we compare a modular data centre to a traditionally built data centre. As an assumption, we have not considered unpredictable costs that could happen, and that there are no significant differences in price in relation to site design and preparation in both types of construction.

One of the elements to consider, and probably the most important, is the operating costs and in particular energy costs, of which energy cost represents a range from 55% to 70% of the total of the operation cost.

Also, we need to take in consideration that there is a range of variables that can lead to a reduced operational cost for the modular construction compared to the more traditional operation of data centres. As with the modular structure, we have greater flexibility to add or substitute with more energy-efficient technologies.

As a final note, we have seen that we need to consider quite a considerable number of options while we try to assess the cost of deploying a data centre, this is valid for both types of data centre construction. As we have collected data and cleaned the data to remove practical information from a few constructions sites only in Europe we have evaluated that cost savings can be achieved in modular construction is the preferred option, with the critical elements for this option being:

1. Reduced times
2. Reduced number of complex processes for installation and commissioning
3. Significant reduction of energy consumption, greater energy efficiency
4. Potentially easier decommissioning and redeployment

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[7] Berkeley modular. (n.d.). Berkeley Group. https://www.berkeleygroup.co.uk/about-us/our-brands/berkeley-modular

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[13] Measuring to improve: Comprehensive, real-world data center efficiency numbers. (2012, March 26). Official Google Blog. https://googleblog.blogspot.com/2012/03/measuring-to-improve-comprehensive-real.html

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[21] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). Chapter 4. The time value of money. Engineering economy.

[22] Decommissioning & Redeployment Costs, by Author

[23] Microsoft finds underwater datacenters are reliable, practical and use energy sustainably. (2020, September 16). Innovation Stories. https://news.microsoft.com/innovation-stories/project-natick-underwater-datacenter/

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