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# WHY WOULD LOCATION-BASED SCHEDULING BE APPLICABLE FOR OFFSHORE OIL AND GAS CONSTRUCTION?

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## ABSTRACT

The focus of this research is in testing the applicability of location-based scheduling within the offshore oil and gas construction domain. The case investigated is a larger oil and gas field undergoing refurbishment in the Danish sector of the North Sea. The exploratory case study took a deductive approach by analyzing the existing location-based scheduling literature. The theoretical patterns allow testing the applicability of the theory in the offshore construction domain. Adapting the patterns from the construction context to the offshore oil and gas construction context. With the knowledge of why and how from a theoretical perspective, we analyzed the original oil & gas construction schedule which is based on critical path method. This analysis provides knowledge about how location-based scheduling is applicable from an industrial perspective. This paper contributes knowledge by testing the theory of location-based scheduling in the offshore oil and gas construction context.

## KEYWORDS

Job-sequencing, Location-Based Management System, Offshore, Oil and Gas, Work structuring

## INTRODUCTION

The offshore oil and gas industry, with its producing platforms positioned in oil fields far offshore, continuously develops and seeks to mitigate the risks of cost overruns from construction, maintenance and refurbishment. These activities would require production (Findlay et al. 1989) to reduce its capacities for safety and practical reasons, which has significant financial impact due to lost revenue (Alonso et al. 2018; Halvorsen-Weare and Fagerholt 2017). Potential lost production emphasizes the high requirements for planning;

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ensuring that parts, equipment, resources and locations are available. Besides the operations planning, planning of the platform activities is also required to ensure construction productivity rates. Gupta and Grossmann (2012) presented a linear program to optimize oil field development, whereas Carvalho and Pinto (2006) focused on production through infrastructure. Halvorsen-Weare and Fagerholt (2017) presented a method for scheduling and optimizing supply logistics around the oil field. Sabri et al. (2015) presented a review of project management literature in the context of offshore oil and gas, including planning. These authors use critical path methodology (CPM) for the planning methods which they introduce to offshore oil and gas construction.

In the field of lean construction, the understanding of construction as a production system was developed with the theory of transformation-flow-value by Koskela (2000). The Last Planner® (LPS) System of Production Control (Ballard 2000) was introduced to plan and control the complexity in construction projects through collaboration and commitments among trades. Location-based management system (LBMS) was introduced by Kenley (2004) to reduce the same complexity in construction. In offshore oil and gas, lean construction has previously been developed by Kalsaas (2013). Inspired by the Last Planner System, Kalsaas (2013) investigated how to improve the buildability of offshore platforms. However, LBMS has to the knowledge of the authors not previously been used in offshore oil and gas construction context.

Therefore, this research project was motivated by the potential of optimizing construction planning by adapting the lean construction method location-based management system (LBMS), as introduced by Kenley and Seppänen (2010). It was decided to proceed with LBMS methodology. Olivieri et al. (2018) presented how location-based scheduling (LBS) could be applied in the construction industry without social interaction, which would have been required for testing LPS in a similar setting (Ballard 2000). Olivieri et al. (2018) illustrated how LBMS could improve flow and resource usage by converting CPM schedules to LBMS schedules. Seppänen et al. (2014) further developed the understanding of location-based scheduling and its impact on productivity from a construction management perspective. The scope of this research is to develop understanding of the location-based scheduling methodology and evaluate if it could be applicable in the offshore oil and gas construction industry.

The first part of this research is a literature review presenting the gap in the existing body of knowledge and this research contribution to fill it. The second part presents the offshore oil and gas construction domain. Third part give an understanding of the exploratory case study, displaying literature patterns and if LBS is applicable in the new domain of offshore oil and gas. The results are then presented and discussed along with implications in the offshore oil and gas industry.

## **METHOD**

The framework for this exploratory single case study is inspired by Yin (2014) and used to test existing theory as described by Voss et al. (2002). A deductive approach was chosen to understand why and how the theory of location-based scheduling could be applied to offshore oil and gas refurbishment. This was accomplished by first identifying theoretical

patterns and secondly analyzing the empirical data for similar patterns. To ensure replicability and internal validity the approach and results are listed in the sequence the case study unfolded as proposed by Yin (2014). Two workshops and a final presentation of the findings were planned in cooperation with the case owner. The intention was to develop the external validity and to avoid potential misinterpretations of the original schedule (Yin 1994). It was found necessary to have multiple participants, with different perspectives on the planning and scheduling of the construction works. The literature review was conducted by searching the databases: Scopus, Google Scholar, and IGLC. The first search string contained: “LBMS”, “location-based scheduling” (LBS), “line-of-balance”, “repetitive scheduling”, “offshore”, “refurbishment” and “construction”. The key word combination was built with LBMS or LBS as the consistent words. LBMS and LBS didn’t give any results in the offshore oil and gas literature. This indicated a gap in the body knowledge for LBMS in offshore oil context. A further literature search was conducted with “offshore”, “planning”, “scheduling” and “construction”, the results of which has been presented in Table 1. The body of knowledge from the offshore oil and gas construction and production revealed that the majority of planning is based on CPM. Halvorsen-Weare and Fagerholt (2017); Halvorsen-Weare et al. (2012); Norstad et al. (2017) all looked into CPM based planning and simulating offshore oil and gas supply vessels. Alonso et al. (2018); Findlay et al. (1989); Gupta and Grossmann (2012); Lang and Zhao (2016) on the other hand developed and presented linear programming for daily or well production and shutdown planning.

Table 1 consists of a comparison of planning and scheduling literature from the domain of: construction, manufacturing and offshore oil and gas. 1<sup>st</sup> column in Table 1 contains the sources reviewed, 2<sup>nd</sup> column to the right is the applicable domain and 3<sup>rd</sup> column is the planning method presented. Table 1 shows LBMS is primarily used within the construction domain and CPM to be dominant in the offshore oil and gas domain.

Table 1: Literature comparison, domain and methods

Source	Domain			Method		
	Construction	Manufacturing	Offshore oil and gas	CPM	LBMS (Flowline)	LPS
Alonso et al. (2018)			X	X		
Ballard, H. G. (2000)	X					X
Bull and Love (2019)			X	X		
Carvalho and Pinto (2006)			X	X		
Findlay et al. (1989)			X	X		
Galloway, P. D. (2006)		X		X		
Gomarn and Pongpeng (2018)			X			
Gupta and Grossmann (2012)			X	X		
(Halvorsen-Weare and Fagerholt 2011)			X	X		
Halvorsen-Weare and Fagerholt (2017)			X	X		
Kalsaas (2013b)			X			X
(Kenley 2004)	X				X	
Kenley, R. (2005)	X				X	
Kenley, R., and Seppänen, O. (2010)	X				X	
Kerzner and Kerzner (2017)		X		X		
Lang and Zhao (2016)			X	X		
Lucko, G., and Gattei, G. (2016)	X				X	
Lucko et al. (2014)	X				X	
Norstad et al. (2017)			X	X		
Olivieri et al. (2018)	X			X	X	
Seppänen, O., Ballard, G., and Pesonen, S. (2010).	X				X	X
Seppänen, O., Evinger, J., and Mouflard, C. (2014)	X				X	
Smalley and Chebotar (2017)			X	X		
Tavallali and Karimi (2016)			X	X		
Valente et al. (2014)	X				X	
Vollmann et al. (2004)		X		X		

## **EMPIRICAL DATA**

The empirical data is gathered from an existing construction schedule which has been generated for the refurbishment of oil and gas production platforms in a large field in the Danish sector of the North Sea. The case owner provided an activity-based schedule from the software package Primavera, which is based on critical path methodology (CPM). The Primavera schedule data was converted to excel and structured according to platforms, then elevations and finally equipment. The activity-based schedule consisted of activities and durations, the dependencies and resources kept separate from the activities. Besides the schedule a complete set of 2D drawings was provided. Illustrating each platform elevation in the field, including side views and a list of equipment positions on the platforms. The case owner organized two workshops, first workshop was held with the project planner to clarify wordings, abbreviations and the schedule structure. The second workshop involved an engineer, a foreman and technician to clarify questions regarding activities, dependencies, resources and locations. Additionally, the two workshops led to an increased understanding of the weather impact on activities seen from a planning and practical perspective. The daily operations and safety concerns were elaborated, especially how these were affected by the construction works. After the workshops and completion of the conversion, the case owner facilitated a meeting for presentation of the findings. As directors and planning experts attended the meeting, it also confirmed the generalizability of the approach and method. The scheduling conversion was implemented by using the Schedule Planner module of Vico Office suite by Trimble.

## **RESULTS**

The following section contains the conversion results of CPM schedule to the location-based schedule. The conversion of a CPM schedule into a location based schedule (LBS) has been handled similarly as described by Olivieri et al. (2018). Presenting 3 similar cases conducted within the construction focused on activities containing resources. This was not considered important for the confirmation of applicability in the offshore context. The initial phase of the conversion was used to understand the locations. Following the logical layers as described by Kenley and Seppänen (2010) page 133-144. After creating the location breakdown structure, all activities were entered with original durations and dependencies.

## **LOCATION BREAKDOWN STRUCTURE**

The LBS was defined as follows; first through review we found the structure from construction projects, then we investigated the available 2D drawings, organized them in platforms, then by elevation heights. Kenley and Seppänen (2010) describes how locations are hierarchically broken down and structured for construction. The hierarchy is organized from the highest independent levels such as the overall building. Which contains the middle and lower levels, including logical locations of physical and non-physical character (Kenley and Seppänen 2010). Olivieri et al. (2018) define tasks by location using logical layers, describing how crews complete a location at the time, also described by Kenley and Seppänen (2010). Valente et al. (2014) divides the locations in equal sizes according to the trades expected durations.

## OFFSHORE PLATFORMS

In the offshore oil and gas fields the platforms and their geographical position are to be perceived as independent locations / structures. This makes the platforms hierarchically highest from a location break down perspective. The location break down levels are described in comparison to the presentation of construction locations by Kenley and Seppänen (2010).

1. Highest levels which are the structurally independent platforms, in construction this could be the buildings, stadium etc.
2. Middle levels are elevations levels also defined as decks of the platform, in construction it could be risers, floors or bays.
3. Lower levels are equal within each geographical zone at each elevational level in construction apartments or zones.

Figure 1 illustrates the side view of platform “A” which is part of the case owner’s main objectives for their refurbishment project. The elevations are listed in the left side with feet above sea level and areas marked with alphabetic numbering. In figure 2 the ‘cellar deck’ at platform A at elevation of 22 feet above sea level is displayed and is in resemblance with floor drawings from a construction site.

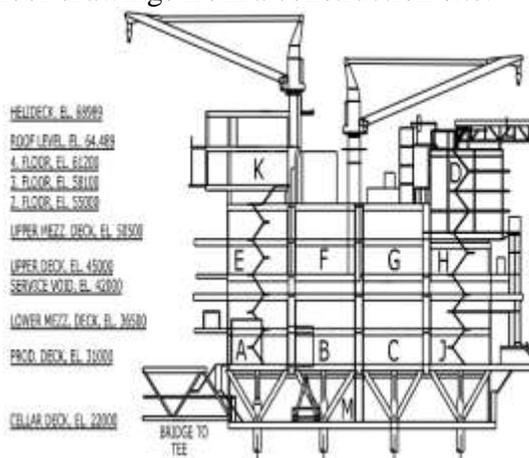


Figure 1: Side view of platform A elevations

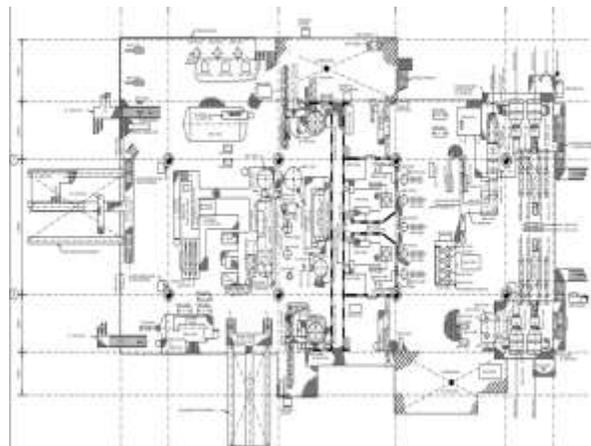


Figure 2: View of cellar deck el. 22 at platform A

## ACTIVITIES AND DURATIONS

The activities in the original CPM schedule were structured according to the platforms by abbreviation. The activity lines were then further structured according to elevations and the equipment on each elevation. Activities were categorized as: scaffolding, electrical, mechanical, painting, rigging and service. These were structured with durations in budgeted hours, completed hours and start-finish defined as calendar dates. The planner confirmed the work breakdown structure, how the tasks were organized, and abbreviations used in the original schedule.

The activities could then be perceived as similar to location quantities and thereby repetitive as seen in Kenley and Seppänen (2010), and organized according to the external

logical layers as described by Olivieri et al. (2018). With the external logic considering how the locations affect the flow of the tasks. The conversion of the CPM schedule into LBMS flowline was done by following the logical layers, but differing from Olivieri et al. (2018) in not considering whether the activities were resource loaded. Further analysis of the activities sought to identify repetitive activities, by identifying similar activities going through multiple locations. To broaden the understanding of the repetitive activities, it was investigated whether similar activities were assigned to equipment in differentiating locations. The equipment lists made it possible to pair similar equipment descriptions by having their locations revealed within the 2D drawings. This made it possible to update the lowest levels of the location structure, where this was required for accuracy. The workshop with the technical experts further developed the understanding of the activities and how they're logically linked together. Diagram 1 illustrates repetitive activities in the original CPM schedule. The flowlines in diagram 2, delivers a visual illustration of the same activities as diagram 1. The seemingly similar activities are with different activity speeds or productivity rates, which also is notable in the 3<sup>rd</sup> column in diagram 1 however less visual if studying the CPM schedule. The paint activities on the various well heads are identical tasks and further LBS accuracy could have been applied, which was confirmed during the workshop with the foreman, engineer and technicians. This could be explained as typos in the original schedule, easily recognizable in diagram 2. This visually illustrates the differences in durations between the tasks by their individual degree of angle. It could also be interpreted as a problem with the production rates and internal logic, leading to task collisions and interruptions as Diagram 2 illustrates.

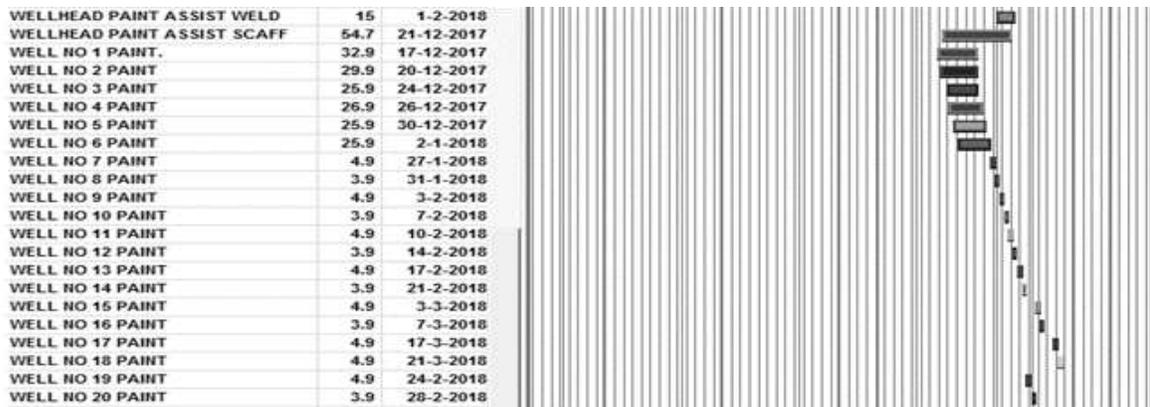


Diagram 1: Example taken from the original activity-based schedule

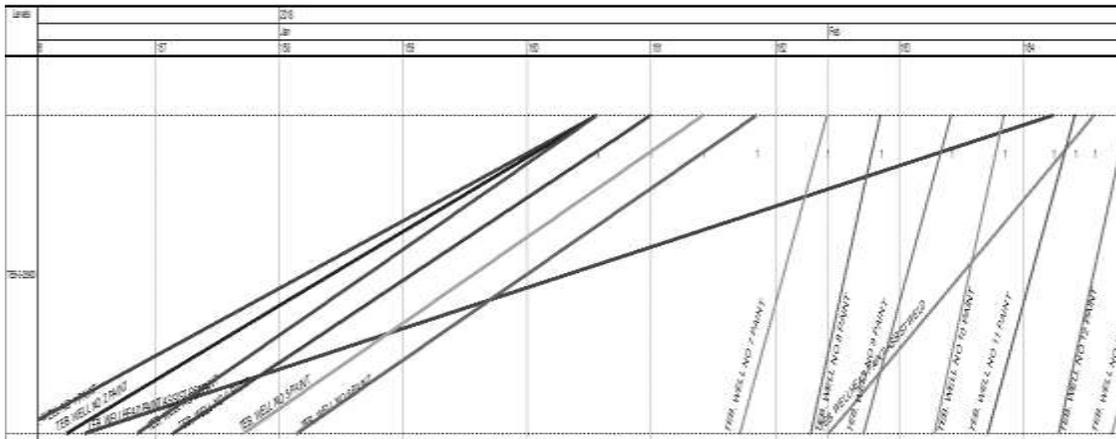


Diagram 2: Direct conversion of diagram 1 into Vico office scheduler

## DEPENDENCIES

The CPM activities and their technical or logical dependencies were not clearly defined or outlined in the original CPM schedule other than start-finish and order of appearance. The workshop with the engineer, foreman and technicians produced the dependencies which helped define the amount of resources and equipment as well as specific dependencies between the activities. Olivieri et al. (2018) used logical layers for the conversion of the CPM schedule into flowlines as described by Kenley and Seppänen (2010). The location dependencies developed through the understanding of the logical sequencing between activities in various locations. The location dependencies are illustrated in diagram 2, where multiple activities are executed simultaneously, this could potentially delay the completion of the individual tasks and affect the overall performance. Furthermore, location accuracy was required for segregation among activities which were assigned to specific platform levels. Additional dependencies for teams working above and below each other were not established in the original schedule, these were visually identified and re-organized in schedule planner. As the activities were loaded with budgeted hours, it was possible to introduce quantities in terms of hours to the schedule. Then based on the expert evaluations, the activities resources could be added. Diagram 3 shows resource consumption in the schedule, varying from 20 to 80 technicians in peaks divided between five trades. The case owner commented on the resource varians, these had led to issues with accommodation on the platforms, to mitigate last minute solution had been required. The CPM schedule hadn't been able to identify the causes for the peaks as these are not related to the critical tasks but rather multiple, simultaneous activities.

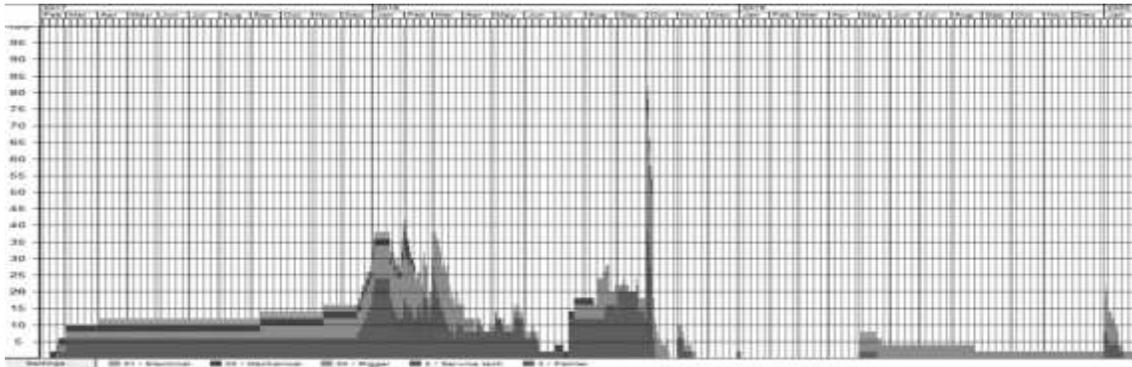


Diagram 3: The resource consumption divided between 5 trades

## DISCUSSION

### RESULTS

The offshore oil and gas literature indicated a preference for using CPM as other industries (Galloway 2006), when planning construction (Carvalho and Pinto 2006; Gomarn and Pongpeng 2018; Norstad et al. 2017; Sabri et al. 2015), production (Findlay et al. 1989; Lang and Zhao 2016) and maintenance (Alonso et al. 2018; Halvorsen-Weare and Fagerholt 2017). None of these consider resource leveling or workflow as Olivieri et al. (2018), neither did they consider productivity as Lucko et al. (2014) and Seppänen et al. (2014). In comparison to the provided CPM schedule the LBMS schedule illustrated inconsistency, which supports Olivieri et al. (2018) results, but they also found that CPM had similar feature for critical activities.

Resource levels, and production rates were visually demonstrated here, illustrating the inconsistencies from the CPM schedule. It could be argued that these key findings demonstrated imbalance in construction planning due to past methodologies. Kenley (2005) illustrates similar irregularities and argues for these to be production rate related which only supports the findings here.

Kenley (2005) similarly showed a direct conversion from a CPM schedule to a flowline schedule. Developing it from repetitive activities throughout the majority of its locations. The location quantities here were developed from hours, some might argue that this could be developed differently. As the material quantities could also have been loaded into each location using Vico suite.

Findlay et al. (1989); Norstad et al. (2017) illustrates a high focus on safety over time within the offshore literature, were Kines et al. (2010) in the context of construction presented how leaders with positive effect communicated about safety and risks. From an offshore oil and gas perspective it could be interesting to understand more about whether LBMS could affect safety during planning which Kalsaas (2013); Kalsaas (2013) also earlier addressed. From a safety perspective, the LBMS schedule allowed visual interpretation of task collisions. But also, if activities are executed simultaneously above or below each other, identifying risk of dropped objects. Where Smalley and Chebotar

(2017) used CPM to develop a risk management framework and determine probability of occurrence. It could be argued that LBMS would allow risk management through risk identification in advance, also seen in Kenley (2005) as production rate predictions. From a construction and planning perspective multiple features and aspects are similar in oil & gas construction. Further developing the understanding of how to apply LBMS in the offshore oil and gas industry, would require further research.

## **IMPLICATIONS**

As this was the first step towards testing LBMS theory in in the domain of offshore oil and gas refurbishment. This conversion has further implications within the offshore oil and gas domain as the potential improvements here are still unexplored. It could be proposed to have similar implications in the offshore oil and gas maintenance, operations management and new build as their planning aspects are similar.

From an offshore oil and gas construction management perspective, it might be worthwhile to aid managers by optimizing the schedule and reducing operative safety risks. The case owner highlighted the safety factor of technicians not working above and below other teams could potentially reduce the risk of dropped objects between elevations. These safety factors could be positively affected by increased knowledge about the locations of workers in the scheduling phase of the offshore oil and gas refurbishment project and during execution, as operations on specific elevations of the platform are identified by expected start and finish similar to what is described by Kyoo-Jin and Langford (2006).

## **CONCLUSION**

The refurbishment schedule of the oil and gas platforms with its quantity loaded locations led to a comparison with construction. The conversion revealed certain issues with safety, productivity and resource levels which can be related directly to previous research findings. Which supports why LBMS is applicable in the offshore oil and gas construction. The research also demonstrated that the logical layers for offshore oil and gas construction can be defined and presented in a flowline diagram.

Further research is required to generate further knowledge of how to apply LBMS in practice and what would be practical implications of implementing LBMS.

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