Construction Vessel Virtual Factory: concept of Decision Support System for offshore pipelay project optimization

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INTRODUCTION

Background - Recently, the worldwide industrial context has experienced radical changes, leading to the introduction of new manufacturing paradigms to handle the ever-greater complexity of the production systems. In particular, the EPC business in the Oil & Gas industry suffered from a substantial reduction of the markup and faced a gradual increase of the complexity, shifting the attention towards new methods to guarantee the efficiency and the effectiveness of the projects.

The engineering digital path - The Virtual Factory concept is well known in the literature, but its application in the O&G field is quite new: it introduces a broader perspective for modeling and simulation of complex systems, underlining the need for new unified environments where the performance of assets, processes and production systems together can be tested.
The context of this research is summarized by the Construction Vessel Virtual Factory (CVVF) concept, which represents the Saipem's strategy towards the development of a Virtual Factory simulation model and a Virtual Factory Framework, and a preliminary step of the creation of a Digital Twin.
CVVF can be applied to pipelaying, installation of offshore wind farms and decommissioning projects.

Research objectives - The research focused on the development of a prototype tool, following the guidelines of CVVF concept. This tool supports the selection of the best setup of an offshore pipelaying system, while optimizing the logistic of the supply vessels by taking in consideration the related risks.

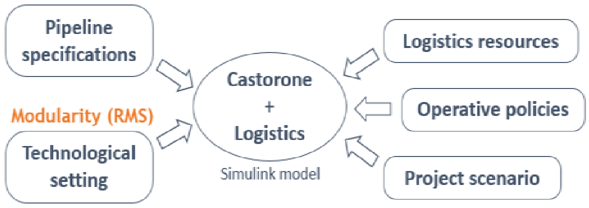
Keywords - Virtual Factory, Discrete Event Simulation (DES), Reconfigurable Manufacturing System (RMS), Decision Support System, offshore pipelaying, optimization, risk management, productivity planning, Digital Twin

Pipelay project definition

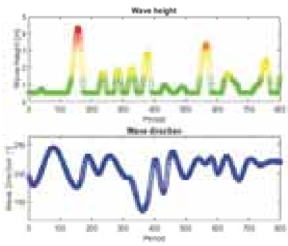
A pipelay project is addressed by a laying vessel, which performs the pipeline assembly (welding multiple pipes) and lays it on the seabed. The considered case involves Saipem flagship vessel Castorone, a state of the art technological vessel for high productivity in harsh environments.
The modular nature of the system allows to frame it under the Reconfigurable Manufacturing System (RMS) paradigm.

EXPERIMENT

The initial analysis of the existing system and its operative policies resulted in the identification of the main problem dimensions. By manipulating the parameters, the decision maker can univocally identify the generic project and perform specific analyses.
The model takes into account both the internal variability (processing times and defectivity) and the external variability (i.e. meteomarine conditions).
An integrated simulation model (MATLAB® Simulink / SimEvents) is built following the Virtual Factory concept guidelines to replicate the behavior of the selected system. The model must consider the complex nature of the marine environment, strongly affecting project outcome. A simulation framework operates on top of the simulation model, performing the comparison between alternative system configurations (rising from the system modularity), selected by the decision maker.

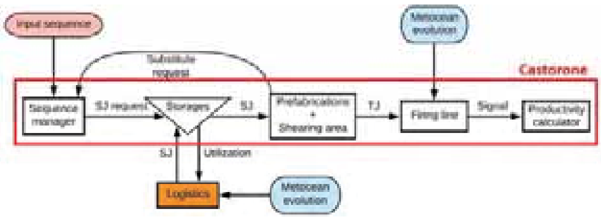


Meteomarine model - Dedicated to the replication of the specific project scenario: described by the set of parameters (evolution of the marine conditions in time) and operating thresholds (reaction of both vessel and logistics to the marine environment).
It generates the metocean evolution for the simulation model. The meteomarine forecast will be simulated by gradually showing to the system the values of the metocean evolution.



Integrated simulation model - The two submodels replicate in detail the actual internal functioning of the Castorone and the supporting logistics fleet, which strongly impacts on project completion time. They track the movement of each SJ along the system: the target is to complete the pipeline in the shortest time (lowest cost).

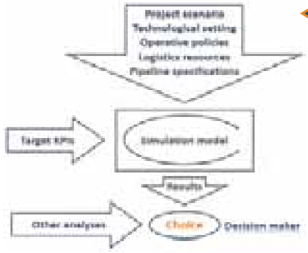
- Logistics fleet: brings Single Joints (SJ, pipe units) from the Marshalling Yard (MY) to the storages, depending on both the metocean conditions and the storage level (prediction of the evolution of each level).
- Castorone: picks the SJs from the storages and brings them to the first assembly stage (two *prefabrications* in parallel generate the triple joints, TJ) and to the second stage (the *firing line* generates the pipeline).



Simulation framework - Allows to compare alternative processes (modularity; e.g. welding technologies), internal policies and storage replenishment strategies, to quantitatively support decision making. It may find out that different system settings are more effective on different projects or different scenarios (e.g. season).

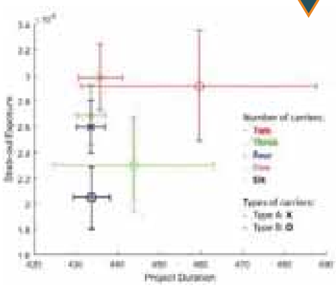
Observed metrics

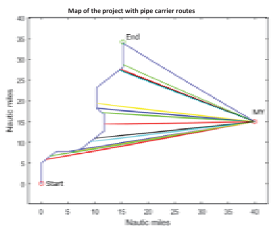
- Project duration: time to complete the pipeline.
- Number of trips: performed by the pipe carriers.
- Stock-out risk exposure: ad-hoc measure of the risk of stock-out.

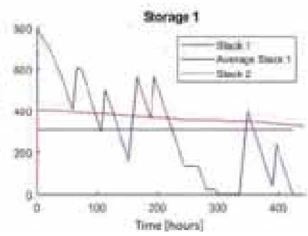


The constraint of the system is to comply with the input sequence: the pipeline is a heterogeneous combination of SJs belonging to three different categories (i.e. bare pipes, pipes with anodes and buckle arrestors). This detail makes the model extremely complicated, since it must deal with rejection of the defective welds (both triple joints and final pipeline).

Experiment - The tool has been applied to the case of the best logistics configuration selection (i.e. assuring lowest project duration and stock-out risk, given the considered project scenario), based on a complete simulation campaign.
In the example pipe carrier type A is bigger and slower, type B is smaller and faster.
The results show a very clear minimum duration frontier and different behavior of the two types, as expected. All project uncertainties are considered and allow risk quantification.







CONCLUSIONS

The prototype demonstrated that a single model can replicate the system dynamics on multiple detail levels and suggest adequate choices to the decision maker based on the obtained data. The analyses can be performed on any system parameter and the metrics set accordingly. Historical data were used as input to provide an outlook on the project outcome.

Future developments - The second pillar of Saipem's strategy for the effective application of a Digital Twin is the development and extensive utilization of real time monitoring tools for offshore operations. Moreover, in the future this approach can be used for other sectors such as large windfarms prefabrication and installation or platform decommissioning.

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