Concept Selection; Theory and Practice

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Abstract

We teach that Concept Selection techniques should be used in the early phases of product development when stakeholder are known and when requirements are established. We hear in practice that managers and engineers bypass Concept Selection and jump into realization, based on the assumption that it takes too much time.

In the Systems Engineering Study Group (SESG) in Kongsberg we have discussed what Concept Selection techniques are, what the benefits are of applying these techniques and what the roadblocks are to use them in practice. We finish with some ideas how to introduce these techniques in a practical way.

Introduction

We teach Concept Selection techniques as part of the first course Fundamentals of Systems Engineering of the Master Systems Engineering (MSE) at Buskerud University College (BUC). Concept Selection takes place once the needs of the stakeholders are articulated and the the requirements are defined. One of the techniques taught is Pugh matrices, where concepts are compared against a set of criteria by means of a matrix.

The subject Concept Selection was chosen because the perception is that in practice project leaders and engineers jump to a solution based on a combination of gut feeling and cost feeling. The use of techniques such as Pugh matrices is perceived as too time consuming and hence ignored. At the same time the perception is that the results of skipping Concept Selection are suboptimal systems, where quality suffers from time pressure.

Concept Selection

The course Fundamentals of Systems Engineering proposes a standard Systems Engineering process starting with stakeholders to find their needs. The project goal is formulated as a simple and clear Need statement. The needs are transformed into requirements setting the stage for he development and engineering process. Here the first step is Concept Selection, where multiple concepts have to be proposed. These concepts are compared to select the most suitable concept(s).

A commonly used technique is Pugh matrices, proposed by Stuart Pugh [Pugh 1981]. A Pugh matrix has the concepts as one axis and the criteria on the other axis. Every field of the matrix contains an assessment of that specific concept for that specific criterion. Tis basic concepts van be extended by adding weights per criterion. See Figure 4 for an example of a Pugh matrix with weights and numbers. Figure 8 is an example of a simpler matrix without numbers, instead + (good), S (Same), and – (bad) are used.

FMC case studies

The first two students that completed their MSE chose for their master project to apply Pugh matrices for Concept Selection in practice. Halvard Bjørnsen applied the technique on the selection of an optimized swivel for a flowline [Bjørnsen 2009]. Dag Jostein Klever applied the technique on the selection of subsea connections [Klever 2009].

Figure 1 shows the context of the optimized swivel study. At the bottom of the sea in oil production fields a flowline connects the Pipe Line End Termination Structure (PLETS) with the manifold. The flowline is a huge pipe for the transport of oil or gas that has to withstand large pressures and temperatures. At this moment every flowline is custom designed and manufactured to fit the specific geography at the sea bottom.

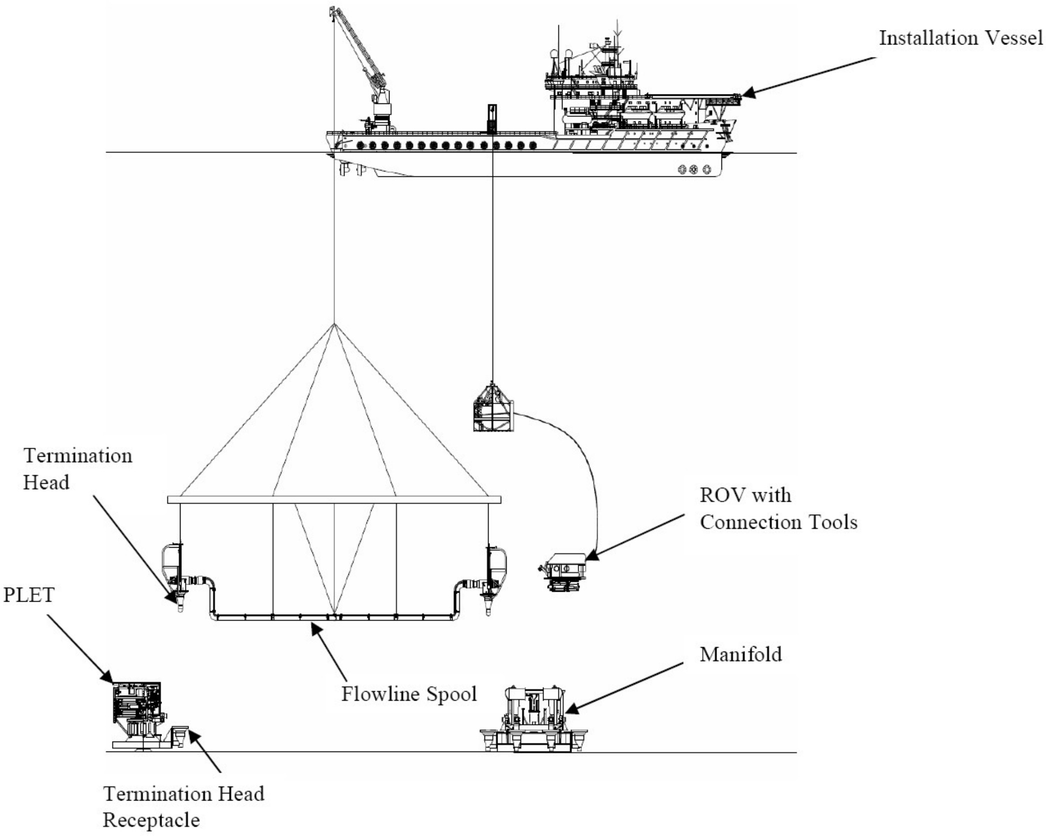

Figure 1. Installation of a rigid flowline spool

The study looks into the possibility to make a more flexible flowline by inserting a number of swivels. These swivels act as hinges, providing a degree of freedom of the angle in the flowline, see Figure 2. If the flowline has this additional flexibility, then the flowline can be produced from more standard components. The use of standard components can lower cost, and also provides much more logistics flexibility.

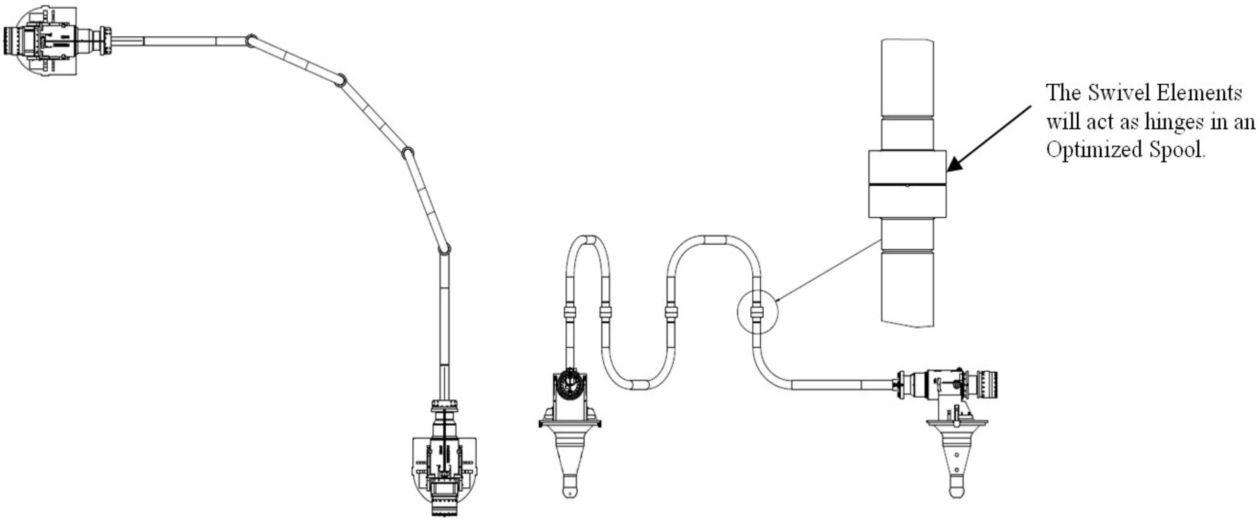

Figure 2. 3D drawing of the Optimized Flowline Spool and with a detail section of the swivel placement

Bjørnsen made an inventory of available swivel technologies in FMC that can be used as starting point for the concept selection. He found three alternatives, visualized in Figure 3:

- a CBV swivel that can rotate during installation time, and locked afterwards
- a clamp swivel that also is locked after installation
- a dynamic swivel that by means of a patented casket can still rotate after installation

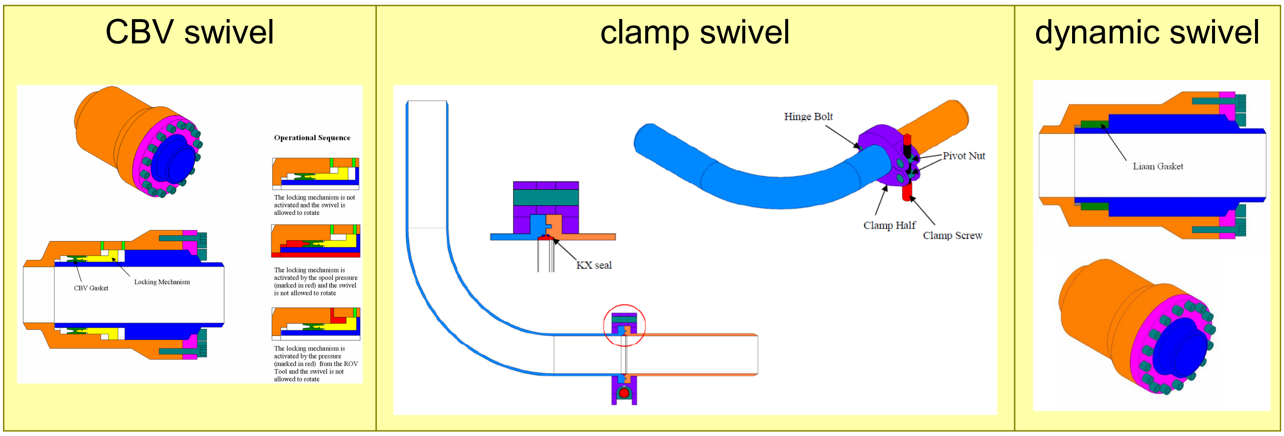

Figure 3. Three concepts for a swivel element in a flowline spool.

Figure 4 shows the Pugh matrix comparing these three alternatives against maturity, cost, design robustness, installation and operation characteristics. This Pugh matrix uses weights per group of criteria. Design robustness and operational characteristics are the most important criteria with 25 points each. Individual criteria are scored on a scale from 1 to 5, where 1 is bad or poor, and 5 means very good, highly desirable.

Evaluation Criteria	Weighed Points	Concept 1. CBV Swivel 		Concept 2.Clamp & KX Swivel 		Concept 3. Dynamic Swivel 	
	0-100	Points, 1-5	Weighed Points	Points, 1-5	Weighed Points	Points, 1-5	Weighed Points
Maturity	10						
Development level		5	50	2	20	2	20
Cost	20						
Hardware Cost		4	80	2	40	5	100
Development Cost		5	100	2	40	2	40
Design Robustness	25						
Design Life							
Swivel Cycles		5	125	3	75	5	125
Pressure Cycles		5	125	4	100	3	75
Pressure Range							
Internal		4	100	4	100	4	100
External		2	50	5	125	2	50
Temperatur Range		4	100	4	100	4	100
Installation	20						
Initial Installation/retreivel		2	40	3	60	4	80
Connection/disconnection		2	40	4	80	5	100
Operation	25						
Swivel Resistance		1	25	4	100	5	125
Spool Length Short		1	25	4	100	5	125
Spool Length Long		3	75	5	125	5	125
Hub Loads		2	50	4	100	5	125
∑ Points	100		985		1165		1290

Figure 4. Pugh matrix for the concept selection of the swivel element.

The selection matrix shows that the dynamic swivel scores best in all aspects, except for pressure performance (less good in pressure cycles and external pressure), and except for development cost where the CBV swivel scores best.

Dag Jostein Klever worked on the concept selection for the connection between two subsystems of the Workover Stack. The Workover Stack, see Figure 5, connects the Rig to the so-called X-mas tree. When the surface conditions at sea get bad, for example in case of storms, then the rig and the X-mas tree must be disconnected safely, without any spillage of oil or gas. The lower Riser Package (LRP) and the Emergency Disconnect Package (EDP) are designed to facilitate fast and safe disconnection.

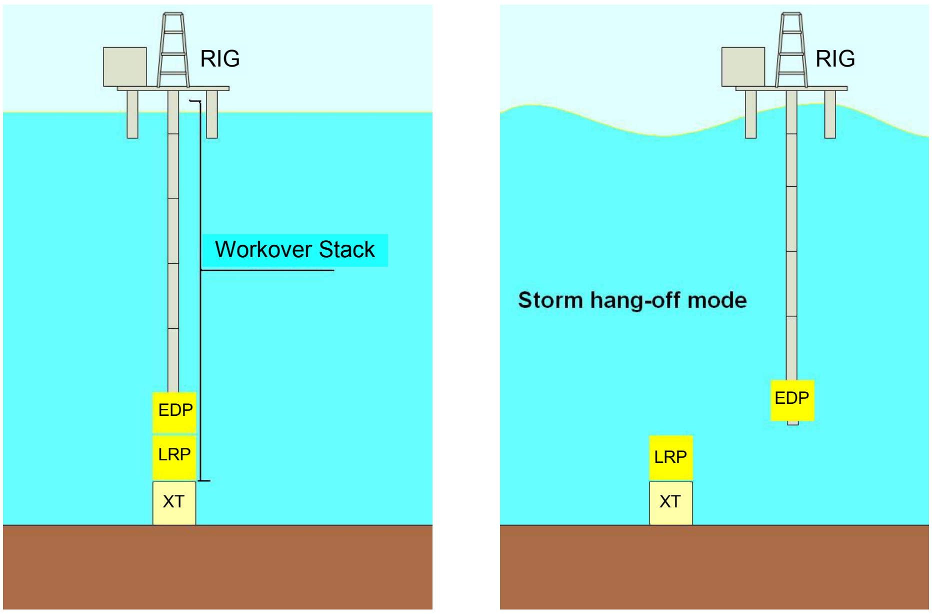

Figure 5. Workover stack. EDP is the Emergency Disconnect Package, LRP is the Lower Riser Package. These units are designed such that they can be disconnected safely in case of

emergencies. XT is the so-called X-mas tree, the actual tree of sub-sea valves.

The EDP and LRP have many electrical interfaces. These interfaces are currently implemented as cables coming from EDP that have to be connected with connectors to the LRP, see Figure 6. These connectors can easily disconnect when needed. The current solution has a few disadvantages:

- A Remote Operated Vehicle (ROV) is needed to make the connections.
- The connectors can be damaged which may require costly repairs of the EDP

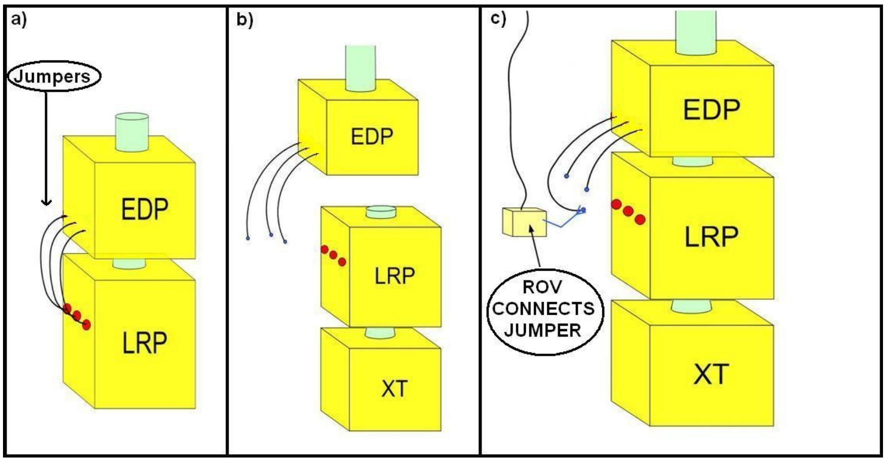

Figure 6. The current solution for electrical connections when disconnecting and reconnecting is by using cables with connectors at one side. A remotely operated vehicle restores the sub-sea connections.

The use of the ROV is costly. Repairing the EDP is even more costly, and the extended down-time of the field in case of damaged connections causes a big loss of income for the oil operator. Klever looked for connection concepts that overcome these disadvantages.

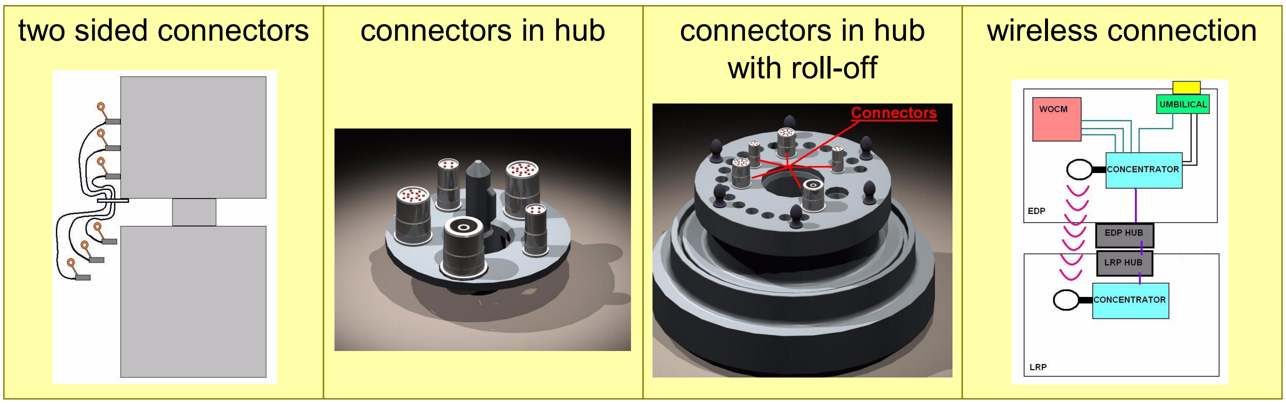

Figure 7. Four concepts for the electrical connection between EDP and LRP.

Figure 7 shows four concepts that have been discussed successively. The first concept replaces the fixed wires at EDP side by connectors. The idea is that when a connector is damaged that then only the wire with connectors has to be replaced. This relative small change does not change the need for a ROV for connection. The second concept moves the electrical connection into the hub. When the EDP is placed onto the LRP mechanical alignment guides the connections into proper placement. During the discussion f this concept a new requirement popped-up: the connection of EDP and LRP must be possible under significant angles, the so-called roll-off. The roll-off requirement triggered a new variant of an in hub connection, concept 3. Finally a more revolutionary concept was added: a wireless connection where all electrical interface are multiplexed over one connection.

Evaluation Criteria		Score	Concepts 1	2	3	4
Time to connect						
	Need for ROV		-	+	+	+
	Design		-	+	+	+
Robustness						
	Connector Design		-	S	S	+
	Number of parts		-	-	+	+
	Handle roll-off		+	-	S	+
	Influence other		+	S	-	S
Redundancy						
	Design		+	-	-	S
	Interchangeability		+	-	-	-
Cost						
	HW Cost		-	-	-	-
	Manufacturing Cost		S	S	-	S
	Engineering Cost		+	-	S	-
	Service Cost		-	+	+	+
Maturity			-	-	S	+
		Σ -	7	7	5	3
		Σ S	1	3	4	3
		Σ +	5	3	4	7
		Position	3	4	2	1

Figure 8. Pugh matrix for the Concept Selection of the connection between EDP and LRP.

The Pugh selection matrix, shown in Figure 8, shows that the wireless connection, concept 4, scores best overall, with only two disadvantages: This concept is less compatible with the past if it is implemented as sole connection and has less redundancy, and the engineering costs are higher since it is a revolutionary new design. The benefits are that it provides a robust connection that is easy to install without ROV.

Discussion of Concept Selection in Practice.

After the presentation of both case studies we discussed Concept Selection in practice. The discussion was triggered by the lessons learned at the end of the presentation, see Figure 9.

Important to ”hold back”

Generally we go into technical solutions to early

Hard to ”teach an old dog new tricks”

Tendency to lean towards implementing some form of familiar technology

Introducing technical solutions, while interviewing stakeholders

During concept generation new requirements might introduce themselves, which again can help you come up with a new concept

Figure 9. Lessons learned from applying Concept Selection at the two FMC case studies.

The experience of the students when applying Concept Selection is that the engineering team tends to skip all preliminary steps and to start realization as soon as possible. Fundamentals of Systems Engineering emphasizes the need to understand the needs and problems of stakeholders before being biased by technical solutions. The existing culture conflicts with this approach, it is hard to “teach an old dog new tricks”.

This domain tends to be rather conservative, implementation with familiar technologies are favored. Many stakeholder interviews center around introducing technical solutions, despite the intend to work from needs and requirements. An interesting side effect is that discussion of solution concepts uncover new requirements.

The discussion was initiated by asking the following three questions:

1. Do you apply Concept Selection techniques in your company?
2. If yes, what are the benefits and success stories; If not what are the road blocks?
3. How can Concept Selection techniques be introduced in a practical way?

Application of Concept Selection in companies

Concept Selection is not widely applied in the companies. In one of the bigger companies it has been applied incidentally, with some success. Sometimes it is being applied because the formal process requires it. One of the most positive applications is where the concept selection matrix is used in communication with management and with customers. In this case the matrix is simplified, not too may alternatives and criteria, and traffic light colors to indicate the scoring (green means good, yellow means there is some issue, red means bad).

Benefits, success stories, and road blocks

When Concept Selection is prescribed by process or customer requirements then it appears that the engineering team goes through the motions, but without following its intent. A matrix is being produced, but is mostly for show, rather than adding value. When it is being used as intended then it brings several benefits:

- documentation for the future
- basis for discussion in project groups
- closer to an appropriate solution
- accountability of the engineering team for the solution
- visual communication tool
- ensures structural process

When Concept Selection is not being used then the following road blocks are mentioned:

- culture
- the believe that a problem and its solution are trivial
- not prescribed in process
- benefits need to be shown and proven
- management need to be convinced
- management lack of knowledge of these techniques
- political resistance, different perspectives of stakeholders
- hard to convince experienced engineers (“old dog story”)

How to introduce Concept Selection is a practical way?

The discussion resulted in the list of ideas below. Note that there is some tension between ideas provided here and previous remarks made in response to previous questions. For example, when

Concept Selection is part of the company processes, then it is being applied to satisfy the system rather than following the intend. That doesn't mean that embedding it in the processes in itself is bad, but apparently more is needed to make it work.

- Use it to present decisions to customers or managers
- Offer company wide training
- Show the bottom-line benefits
- Integrate Concept Selection in the development processes (standardization)
- Show convincing examples from real projects to management
- Facilitate workshops in real projects
- Do pilot project
- Create an environment for Systems Engineering (fostering the discipline, f.i. Via networking)
- Create an environment for longer term R&D, where time pressure doesn't kill new insights, ideas, techniques or methods

Summary and Conclusions

Concept Selection is one of techniques being taught in the Master Systems Engineering. The technique is applied when needs of stakeholders and requirements have been collected. The idea behind Concept Selection is that a good solution is achieved by analyzing a few alternating designs and comparing them by a set of criteria that fits the problem.

We observe in practice that managers and engineers tend to skip this phase and prefer to jump into a realization. The perception is that Concept Selection is time consuming, spending time on it can not be afforded.

From the discussion it became clear that we have to show more clearly how Concept Selection improves the development effort, rather than slows it down. We need to show real examples and we also have to show the bottom line impact of applying Concept Selection. Too often we show the technique itself, without translating the impact in bottom line figures.

Acknowledgements

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References

Halvard H. Bjørnsen, Concept Development Case Study; Swivel Element for an Optimized Flowline spool, Master Project Paper, Buskerud University College, 2009

Dag Jostein Klever, Needs and concept analysis; A case study for subsea connections, Master Project Paper, Buskerud University College, 2009

S. Pugh (1981) Concept selection: a method that works. In: Hubka, V. (ed.), Review of design methodology. Proceedings international conference on engineering design, March 1981, Rome. Zürich: Heurista, 1981, blz. 497 – 506