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MANAGING THE MULTIPROJECT ENVIRONMENT

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ABSTRACT

This paper deals with one of the major topics today in the field of project management, i.e. managing the multiproject environment. It introduces a conceptual framework describing the multiproject environment on three levels, strategic, tactical, and operational. The strategic level focuses on global business decisions, and business and project portfolios. The tactical level focuses on the formation of projects on the basis of business decisions, engineering tasks to be performed, and product-related deliveries to customers. The operational level focuses on the design of engineering teams performing product development work according to the delivery plan. On this level, each of the identified projects on the tactical level is defined according to its Work Breakdown Structure (WBS) and creation of collaborative work packages (WP) enabling inter- and intra-organizational coordination of people and integration of their tasks. The missing link between the strategic level and the tactical level is how to transform business decisions within the strategic portfolio of a corporation into a project portfolio, a purposefull multiproject organization focusing on deliveries and the supply of products to customers. This missing link transforms the strategic business decisions into a series of projects with a web-like multiproject environment.

Corporations often tend to develop different but parallel/concurrent structures in order to handle major dimensions of complexity, people, product architecture, and technology. People are organized in a basic organization, often a functional structure, while product architecture is reflected in a task- and project-oriented product development structure, and technology is reflected in a complex multiproject environment structure. The methodology used in this paper (DSM, Dependence Structure Matrix) is based on an empirical case showing how a systemic relations and dependence analysis can identify clusters of engineering tasks that form an integrated project structure. The DSM analysis is also used to identify relations between the new project structure and the prevailing basic organizational structure in order to identify where coordination and integration are needed between the temporary project-basedstructure and the basic organizational structure.

In this paper, we describe and examine this transformation of business decisions into engineering tasks and integrated project-oriented organization as a critical aspect of the multiproject environment. The results of this research show how DSM methodology can be used to create a project portfolio byanalyzing business portfolio and engineering tasks forming a multiproject structure. DSM methodology shows how the formation of projects on the tactical level is related to business decisions on the strategic level. This analysis shows also how the multiproject structure is related to the prevailing basic organizational structure.

INTRODUCTION

Product development consists of activities that may be organized in various ways. The traditional approach to product development has been to organize tasks according to corporate functions that are involved on a sequential basis. To increase effectiveness and efficiency in terms of lead-time, cost and technical quality, new approaches are introduced, such as concurrent engineering and parallelization of tasks conducted in cross-functional teams. In such constellations, product development is run in temporary based organizational settings, i.e. projects, according to the mission they have to perform. New projects are introduced as new tasks have to be performed each time new business decisions are made. The mainstream literature in the field of project management has for years focused on what could be named the single project environment, as if corporations run one or more independent projects simultaneously. However, corporations do not run one project at a time or several projects that are independent of each other. Corporations have to deal with an environment in which their projects sometimes compete with each other. There is a struggle and fight for scarce resources, and management sometimes make short-term decisions that are counter-productive from a corporate perspective. All these problems are evident in a multiproject environment. A characteristic of multiproject organization is that a corporation may simultaneously run a series of projects that to some extent are interrelated and interdependent. The dependencies that connect different projects with each other may be technological, knowledge-oriented, product-oriented or interlinked by the deliveries made to the customer. At the same time, there may be projects that are independent regarding the dimensions mentioned above, but which share important resources with other projects, such as people. This creates a web-like multi-level structure that may be called a multiproject environment.

If we see organizations as entities seeking to make money for their survival, we must recognize that business decisions consist of engineering tasks to be performed. This is preferably conducted in a project organization structure, which does not imply that the often functionally organized basic structure is removed. In practice, the temporarily organized projects need to reflect the logics of business and engineering tasks and the long-term logic of knowledge development conducted in the basic organizational structure. The major problem is to find the balance between these two structures, one temporary and the other long lasting, persistent.

The multiproject situation has been recognized recently as a major issue; some indicators suggest that up to 90% (by value) of all projects are conducted in the multiproject context (Payne, 1995). Generally, these projects are smaller than their larger unitary contemporaries and they do not have the luxury of dedicated resources. The vast majority of these projects share resources with other projects and thus the major issue is to find ways of handling resource scarcity according to the overall strategic direction of the corporation.

In recent times, the focus in research has shifted towards the recognized multiproject environment. Several authors have attempted to create an increased understanding of the new situation facing corporations. Sometimes, projects are run in centers stressing a collocation of people. Projects are run as if they are independent of each other. There is a balance between the focus applied in one particular project and the long-term strategy that is conducted in a stream of different projects in which different goals, visions and direction may be seen between projects and long-term strategy (Cusumano et al., 1998). Moving from function-driven projects based on function- or matrix-type structures to organizing people and tasks in heavyweight projects with dedicated management sets new demands on management in general and project management in particular. First of all, there needs to be a balance between a project's demands on autonomy and the functional department's need for technology and knowledge development. It is sometimes difficult to reconcile short-term demands with long-term demands. Other problems that management have to deal with include the transformation of strategic decisions and business decisions into a set of engineering tasks that must be organized as a set of projects in order to utilize project-organizing settings.

The multiproject environment is recognized by Hendrix et al. (1998) as focusing the problem of allocation of scarce resources such as people to the different projects in a portfolio. They suggest flexible resource planning based on long-term, medium-term and short-term planning taking into account the availability of scarce resources and the need for special knowledge. Their analytical tool is labeled the "project-scatter-factor", which is a relation between the number of employees and the number of man-years spent on a project. Their suggestion is to keep this factor as low as possible in order to maintain a high level of project efficiency.

The multiproject environment is seen by Grey (1997) as a nominal umbrella grouping mainly of projects on the basis of interdependencies among projects, sub-projects, or any kind of project-type work activity. Grey suggests that these inter-relationships need to be recognized in terms of vertical and horizontal relationships in order to create a proper coordination of project-type work among different projects. The issue of inter-relationship between organization, individuals and projects is also recognized by Merwe (1997), who suggests a similar solution to Grey (1997) in terms of the coordination of activities among projects in a matrix-based analysis. The relations between projects are recognized by Payne (1995) as a major problem in terms of choice of technical solutions, cost and resource planning, and control.

Our approach recognizes the problem of relationships and aims at presenting a methodology in which strategic business decisions create a business portfolio that takes the systematic analysis of relations between business decisions and engineering tasks as the basis for creating a suitable project structure held together in a multiproject organization. Our method of systematic analysis of relations is well known as the Dependency Structure Matrix (DSM), and is further described below.

Figure 1: CONVERGING MULTI PROJECT ENVIRONMENT

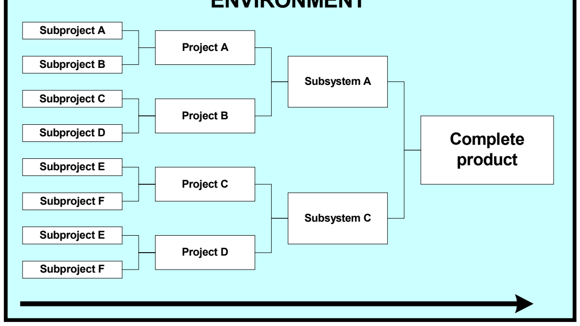
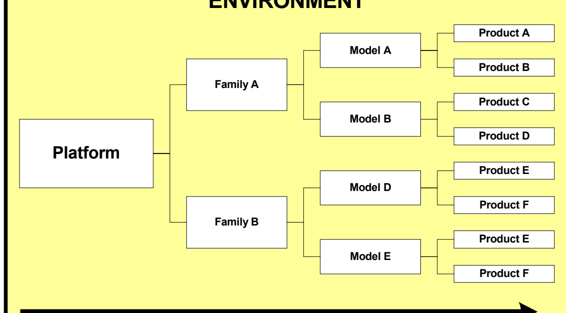


Figure 2: DIVERGING MULTI PROJECT ENVIRONMENT



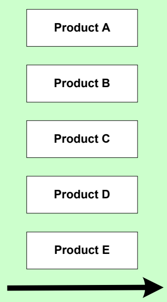
Typologies of the multiproject environment

In the context of corporations, three different types of multiproject environment can be distinguished.

Type 1 (Figure 1). Convergent multiproject environment. A characteristic of this type of environment is that what in one case is a subproject may in another case be an independent or a major project containing other subprojects. Car and aircraft development/manufacturing corporations may be used as examples of convergent multiproject organization.

Type 2 (Figure 2). Divergent multiproject environment. A characteristic of the divergent multiproject environment is that several different projects either share the same background, technology, and product or business decision. An example of the divergent setting is the car industry, in which different models share the same platform, engine or chassis. The outcome of divergent process is a variety of car models, market adaptations, etc. The major issue in such an environment is to coordinate activities according to the relations identified.

Figure 3: PARALLEL MULTI PROJECT ENVIRONMENT



In real life, combinations of type 1 and type 2 are evident, as they exist simultaneously in both the car and aerospace industries.

Type 3 (Figure 3). Parallel multiproject environment. In such cases, different projects may be seen as independent of each other, even if they may share certain resources, such as people, knowledge base, etc. The focus here is not on the output but on the resources used to conduct projects and tasks, while the output in types 1 and 2 is the basis for understanding the characteristics of multiproject environment

Levels of managing the multiproject environment

Managing multiprojects can be seen on three levels (Figure 4); strategic, tactical, and operational. Each of these levels focuses on different empirical issues and different approaches have been suggested for handling projects, from business decisions and formation of projects to creating cross-functional teams. The strategic level focuses on business decisions that eventually form a strategic portfolio of business decisions and projects. The tactical level focuses on the project level and the question of transforming business decisions into a manageable project structure, i.e. the formation of projects based on relations among business decisions and tasks into a multiproject structure. The operational level, the engineering work level, focuses on the single project level and aims at creating collaboration

Figure 4: Levels of Managing Multiproject Environment

MANAGING COMPLEX PROJECTS

Levels of analysis	Empirical problems and questions	Theoretical and methodological approach	Achieved results
Strategic level	What business decision should we make and how does this impact our strategic portfolio? ***Business decisions***	Strategic portfolio management	Design of a stretegic business portfolio Partnership and strategic alliances
Tactical level	How to transform business decisions into a proper project structure? ***Formation of projects. Management of multi project environment***	***Dependece structure matrix (DSM)*** Theory of complexity	***Design of project portfolio Managing multi-project environment***
Operational level	How to obtain integrated systems and cross-functional teams? ***Design of work brakdown structure (WBS) and work-packages (WP)***	Dependece structure matrix (DSM) Theory of complexity, Concurrent engineering, Organizational learning	Design of integrated projects. Creating collaborative work breakdown structure (WBS), and collaborative work-packages (WP)

on an everyday basis between engineers in different corporations working in cross-functional teams.

The **missing link** between the strategic level and the tactical level is how to transform business decisions within the strategic portfolio of a corporation into a project portfolio, a purposefull multiproject organization focusing on deliveries and the supply of products to customers. This missing link transforms the strategic decisions into a series of projects with a web-like multiproject environment.

Aim of the suggested research

The aim of this paper is to develop understanding of the dynamics between the strategic and tactical levels in managing the strategic business portfolio in a multiproject environment. This paper investigate how the Dependence Structure Matrix (DSM) can be used to help managers analyze relations and dependencies between business decisions and engineering tasks on the strategic level in order to design a purposefull multiproject environmenmt, i.e. formation of projects on the tactical level.

The empirical investigation

The Swedish aircraft manufacturing company, Saab, has been developing military aircraft since 1937 and has supplied the Swedish Air Force with many different aircraft. Approximately 3,500 people are employed at Saab in the development and production of military aircraft. The JAS 39 Gripen (Figure 5) is the first aircraft in the new fourth generation of military aircraft, such as the French Rafale, the American F-22 and the European Eurofighter 2000. In the context of the international aircraft industry, Saab is a small company. The Swedish Air Force is already using the Gripen in military operations and

Figure 5 : The Swedish JAS 39 Gripen

training. The strategy of Saab is to introduce the Gripen on the international market in collaboration with British Aerospace. One of the main characteristics of the Gripen is its capability to combine the roles of fighter, attack, and reconnaissance aircraft. This combination of tasks demands great flexibility. Other characteristics are the relatively simple maintenance and support of the aircraft on the ground, enabling rapid deployment of the aircraft on new missions. Almost every military aircraft in the world is designed to operate from permanent airbases with high demands on the condition and length of the runway (apart from aircraft designed for use on aircraft carriers or vertical takeoff and landing). Military operations from permanent airbases enable easier support and maintenance of the aircraft, compared with temporary airbases such as ordinary highways.

Since 1997, there has been a continuous upgrading of the original JAS 39 Gripen intended for the Swedish Air force, together with technical modifications aimed at adapting the aircraft to the export market. The conditions for aircraft development are quite different from the development of other products. An aircraft consists of a large number of integrated systems, many of them very complex, which have to work together in a very limited space and weigh as little as possible. The Gripen aircraft is made up of more than 60,000 components in 450 different pieces of equipment, with about 40 digital computers controlling the equipment. The development of the upgraded JAS 39 Gripen was initially organized in approximately 50 different projects mainly structured as functional upgrades of systems, such as the new Environmental Control System. This resulted in many problems related to technical decisions and priorities.

To ensure the Gripen remains at the forefront of combat systems capability for decades to come, further introduction of high technology is planned. For this reason, pre-development programs in the key areas of propulsion, sensors and weapons are underway.

Future system upgrades will be software-based, cost-effective and relatively straightforward, unlike upgrading programs for older generation aircraft that are typically more costly and require the fleet to be grounded for significant periods of time. This includes the Meteor, Taurus, Brimstone and IRIS-T systems, among others. Additionally, NATO standard pylons will ensure that any suitable weapon in the NATO inventory can also be integrated according to customer needs.

Cockpit adaptation for use with night vision goggles will provide the Gripen with a day and night low-level operational capability. Where required by the customer, a helmet-mounted display will be integrated to further reduce pilot workload in combat environments. Survivability is to be further enhanced by a new, highly advanced EW system and internal jammer and provision for additional chaff/flare capacity through further dispensers in the rear fuselage and air-to-air missile launcher.

The Gripen's state-of the-art communications system, which already includes the world's most advanced in-service data link, will also be further developed to provide improved functionality and flexibility in support of the TARAS tactical radio system. TARAS represents the next generation in communications, providing greatly improved capabilities despite threats from rapidly developing electronic warfare. The core of this system will be common to both the Swedish domestic aircraft and export versions, utilizing the same NATO compatible radios in order to support international operations. Where appropriate, the Gripen will be equipped with a fully NATO compatible IFF system with Mode 4 capability.

While the Volvo RM12 engine, which equips the Gripen today, fulfills all requirements, full authority digital engine control (FADEC) is being introduced. This change will further reduce engine life cycle costs through an increased ability to control engine-operating conditions together with enhanced engine and control system monitoring. It also provides further growth potential for engine performance.

Today, the project management approach at Saab focuses on functional oriented (function-oriented development of business decisions, engineering tasks and projects. The disadvantage of this approach is that the existing multiproject structure is treated as if there were a series of loosely interdependent projects. In this case, the major management issue is the need to apply a considerable amount of coordination between projects seeking to maintain time schedules and milestones, and deliveries to the customer. The result is difficulty in keeping the time schedule and coping with repetitive rearrangements of milestones. The cost of this approach is a loss of focus on system integration (in product variants). In the case of a multiproject environment where the projects are highly interrelated, this traditional approach is reactive and does not solve the problems of coordination and integration.

The complexity of the multiproject environment demands new approaches. What needs to be understood is that all business decisions and products customers buy is not expected to be delivered to customer in boxes but rather in special aircraft batches containing items according to customer requirements and not the logics of technical departments or the logic of production. This requires deliverables to be driven in projects and business decisions and tasks to be organized into a purposefull project structure focusing on deliveries. There is a sequential delivery plan, which means that there is a continuous series of aircraft batches, each containing a series of business decisions and products to be delivered to the customer.

There is a need to balance the need for function-oriented development versus system and product integration by restructuring some of the current development tasks. This means moving some of the tasks or some of their work packages into product variants, or batches. The interaction between function development and system integration needs to be clarified.

Reasons for changing the multiproject environment at Saab

The management at Saab perceived that the present way of running the multiproject environment did not focus sufficiently on systems thinking from the corporate strategic level and thus did not satisfactorily apply a holistic approach to managing the multiproject environment. They considered that the present project management was focusing on projects based on engineering tasks on the functional-basis as if they were run in a single project environment and not on deliveries and customer-oriented products, or the aircraft to be delivered in specific batches. This was relevant for program management as well as for project management levels. Management of projects today can be characterized as coordination of technical functions on a functional basis and not in heavyweight management-driven projects. Resource planning in projects was also conducted according to the prime coordinating mechanism – the time schedule for deliveries – on the functional basis.

The consequence of this approach was that perpetual re-prioritization among projects, subprojects and tasks was necessary, making it difficult to keep to the time schedule, to deliver complete aircraft to the customer on time, and to assure communication among people in functionally organized projects. This created a situation that had consequences also for management, in that they were unintegrated and unfocused in their ability to manage a series of projects for which they were responsible, while all their personnel were allocated to technical functions in the prevailing basic organization. This made it difficult to work in cross-functional teams on the engineering level since these engineering tasks and work constellations were defined according to the logic of technical functions and not the logic of projects.

On the individual level, there was a feeling of sense of insecurity, stress and discomfort among project personnel due to the multi-dimensional management structure – "Too many cooks spoil the broth". Confusion among personnel and a lack of information from management were evident in projects.

At the same time, the customer focus was increased and made the earlier type of organization ineffective. The number of function oriented development tasks was difficult to manage in the case of an entire product variant focusing on deliveries on schedule.

As the work progressed, it became evident that it is necessary to have firm control of the process from development of functionality, through integration in the total system, to an aircraft with specific characteristics ready for delivery to a specific customer, i.e. stronger project control regarding product variants.

Looking at the multiproject environment at Saab, divergent, convergent and parallel multiproject structures can be seen to coexist simultaneously. Basically, the JAS 39 Gripen is in production for the Swedish government, while there is continuous development of new systems to be introduced at different times in different batches according to customer demands. The problem was to find a way of integrating the divergent, convergent and parallel situations. The solutions become the focus on deliveries of batches according to the schedule. Time became the director of the project train, management became the conductor and the engineers became the drivers of each delivery batch.

Management at Saab wanted to investigate and evaluate other approaches to managing a multiproject organization that could help place the focus on deliveries to the customer. The suggested solutions should be based on relevant theory in management and engineering sciences in order to help develop new insights and new solutions.

Research methodology

The main methodological approach underlying this paper was participatory-based DSM analysis.

1. **Identification of empirical issue and design of a DSM.** This step requires dimensions of DSM analysis to be identified. It also includes that strategy is determined. It also requires a decision to be made regarding whether the DSM analysis should be based on components, tasks, parameters or people, and the level of DSM analysis to be determined in terms of Micro, Macro or Meta level (see Danilovic, 2001). This discussion results in the design of one symmetric and one asymmetric DSM matrix. In this research, the design of the DSM analysis was based on business decisions and engineering tasks on an aggregate level. In this case, we decided to apply the DSM analysis to one task – task and one task – basic organization analysis. In both cases, we searched for relations between the exchange of technical information needed to design a proper multiproject structure and the departments in the basic organization at Saab (labeled Material Groups, as these departments follow the technical logic of the aircraft, such as hydraulic and air systems). This step was conducted in collaboration with managers and experienced engineers in a dialog situation. Other DSM designs could also be applied.

2. **Participatory based DSM analysis during a workshop**. After the DSM was designed, we invited experienced engineers and managers from technical departments to take part in the analysis. These participants were assumed to have a specialist background from different technical functions. In this step, we invited people to

participate in a workshop and to discuss every possible relation between all the rows and columns in a/the DSM

3. **Feedback and discussion**. After a few days, the information gathered during the workshop-based session was presented to all the participants in order to evaluate the approach chosen and to share the results obtained with management and engineers at Saab. Besides the research-oriented questions, management at Saab wanted the information and results obtained from the analysis in order to reorganize their own way of running multiprojects.

4. **Publishing papers.** Due to the research interest and the results achieved, a decision was made to write two different papers in order to share the results with the scientific community and other people at Saab, and among other corporations. One of these papers focuses on the methodological aspects and the other on managing the multiproject environment.

The dependence structure matrix (DSM)

Product development is fundamentally a question of problem solving based on information exchange. The need for information exchange is a consequence of complexity, the potential relations and dependencies that may exist between people involved in the product development process, the tasks these people perform, or relations between components in a product structure or chosen technology.

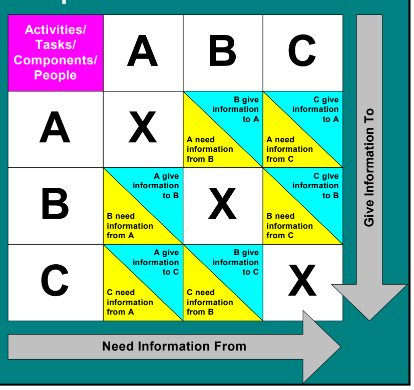


Figure 6 : The Principles of Dependence Structure Matrix

The dependence structure matrix (DSM) methodology is based on a problem-solving foundation using analysis of relations, constraints, and dependencies to define a problem (Steward, 1981). DSM represents and visualizes relations and dependencies among tasks and activities, components and subsystems, and among people and teams. These relations are mapped in a matrix. Figure 6 shows the principles of matrix-based analysis where information is plotted in rows and columns. The intersections between rows and columns contain the identified relation and dependency information. A DSM analysis shows how the design of tasks can be organized for effective problem solving in team-based work and the communication required within and between teams (Eppinger et al., 1994;). The information captured in a DSM analysis is similar to that in a directed graph or a PERT chart; however, the matrix representation makes it possible to create a complete model of the information flow and dependency analysis in describing and analyzing complex projects. Unlike the PERT technique, DSM allows tasks to be coupled or independent.

RESULTS

The basic organizational structure follows the logic of the technology chosen in the aircraft's design. Technical departments reflect the technology of the product and the basic organization at the Swedish customer (FMV). Figure 7 shows the basic organizational structure.

Figure 7 : Saab Basic Organization: Material Group (MG)

01 Complete Aircraft	02 Operational Analysis	03 Quality	04 System Safety and Reliability	05 Weight	06 Survivability	07 Aerodynamics and Performance	08 Structural Dynamics and Loads	09 Stress	11 Development and Test Facilities	12 Flight Test Instrumentation	13 Mechanical and Thermal Environment	20 Operational Performance, General	25 Flight Manual	31A Structure	31B Structure	32 Escape & Oxygen System	33 Landing Gear & Braking System	34 Flight Control System	35 Hydraulic System	36 Environmental Control System	37 Fuel System	38 Secondary Power System	39 Electrical Power and Lighting System	41 Armament Installation	42 General Systems ECU	50 Propulsion, General	51 Engine	52 Engine Installation	61-01 Avionics Software Integgration	61-04 Central Functional Monitoring	61-05 Electromagnetic Compatibility	61-06 Decision Support	61-07 Mission Support	62-01 Systems Computer	62-02 Interface Units	63 Primary Flight Data and Navigation	64 Communication System	65 Identification System	66A Target Acquisition System	66B Target Acquisition System, IR	67 Electronic Warfare System	68 Display and Control System	69 Maintenance Data Recording System	71 Reconnaissance System	72 Weapons Delivery & Control System	79 Central Test Function	80 External Stores	90 Support System

Figure 8 shows part of the strategic business portfolio. Compared to our analysis in Figure 9, the total business portfolio in Figure 8 is more extensive; it relates to different parts of Saab and extends from airframe structure, through systems engineering to software engineering. In this case, we focus only on a number of businesses tasks and activities that are relevant for a specific delivery batch, No. XX. The engineers who participated in the analysis suggested that some of these tasks were not relevant for task – task DSM analysis. However, some of the business tasks in Figure 8, not presented in Figure 9, will be introduced in Figure 11. Due to the military restrictions, we are unable to describe the actual content of each of these businesses decisions and engineering tasks. Therefore, in Figure 8, only the internal numbers are used as identification labels.

Figure 8 : Saab Business Portfolio

PCR	WBS Id
9	EBS04
10	EBS02
12	EBS03
13	VU02
19	64775
24	VU03
46	
57	VU25A
61	VU14A
82	VU01
85	VU12
87	VU24
88	VU21
89	VU12
90	EBS07
99	VU01 , EBS03
100	VU19
101	EBS13
107	
377	EWS39
122	VU23
123	GA107
123	
135	AF03
138	AIU
145	VU12
147	
148	EBS21
152	VU12
155	VU43
160	EBS09
161	
162	VU12
169	
173	
176	IRST.1
185	VU16
212	EWS39
236	
241	
242	EBS26
282	
288	
334	EWS39
373	
379	

Step 1 – Formation of projects in a multiproject environment

The first DSM analysis was task – task oriented (for an overview of different DSM analyses, see further Danilovic, 2001). The purpose in this step was to

Figure 9 : DSM-analysis, Batch XX, MODIFIED

	WBS Id	EBS04	EBS02	EBS03	64775	VU03		VU25A	VU14A	VU12	VU24	VU21	VU12	EBS07	VU19	EWS39	VU23	GA107	AIU	VU12	EBS21	VU12	VU43	EBS09	VU12		IRST.1	VU16	EWS39		EBS26	EWS39
PCR		9	10	12	19	24	46	57	61	85	87	88	89	90	100	377	122	123	138	145	148	152	155	160	162	169	176	185	212	241	242	334
9	EBS04	X				2					1							2		1			1			1						
10	EBS02		X	2								2							3													
12	EBS03		2	X	2																											
19	64775			2	X														3													
24	VU03	3		3	3	X	2			2									2			3			3	1						
46					3		X			2										1			1	1								
57	VU25A							X		2				1																		
61	VU14A								X															1		1						
85	VU12	3	2			2			3	X	3		3	3				3		3		3		3	2	3			2			
87	VU24	2	1						2	3	X			3												3						
88	VU21		2									X																				
89	VU12	1								3			X					3														
90	EBS07	1		1					3		3			X								3		3							3	
100	VU19														X				1					1								
377	EWS39															X																
122	VU23												3				X	2														
123	GA107	3	3	3	2	3		3	3	3	2		3	3	1		2	X	3	3		3	3	3	3	3					3	
138	AIU	1	3						3	2	3	1			1				X	3		1		3		3						
145	VU12							1		3								3		X												
148	EBS21																				X											
152	VU12													2								X										
155	VU43	1			2																		X									
160	EBS09							3	3		2													X								
162	VU12							2	2	2	2			2										3	X	3						
169		2	3		2			1	2	3	3	1				1		3				3		3	3	X					3	
176	IRST.1																										X					
185	VU16																											X				
212	EWS39																												X			
241																														X		
242	EBS26										2																				X	
334	EWS39																1															X

analyze part of the prevailing business portfolio. Due to the number of business cases, we focused only on those that were mostly oriented towards systems development. When the tasks had been identified, participants in the workshop were asked to identify all the possible points of interaction (POI) in this symmetric DSM matrix (Figure 9). This figure shows the results of such an evaluation. Some POIs contain the numerals 1 – 2 –3, where 1 indicates that the identified POIs have relations with a low level of impact on the engineering work, 2 indicates a medium level and 3 a high level of impact.

As we can see in Figure 9, certain tasks do not contain any relevant POIs and can thus be regarded as fairly independent when designing a purposefull project structure. In most cases, there there are identified POIs and we have to consider how these can be grouped in order to

Figure 10: DSM-analysis, Batch XX, FINAL

NEW PROJECT STRUCTURE		WBS Id	VU25A	EBS09	EBS07	VU12	VU12	VU24	VU12	EBS26		VU43	64775	EBS04	VU03	EBS03	AIU	EBS02	VU21	VU12		GA107	VU23	VU12	VU14A	EWS39	VU19	VU15	EWS39	IRST.1	EBS21	EWS39	
	PCR		57	160	90	85	152	87	89	242	46	155	19	9	24	12	138	10	88	162	169	123	122	145	61	334	100	185	377	176	148	212	241
PROJECT 1	57	VU25A	X		1	2																											
	160	EBS09	3	X				2																	3								
	90	EBS07		3	X		3	3		3				1		1									3								
	85	VU12		3	3	X	3	3	3					3	2			2		2	3	3		3	3							2	
	152	VU12			2		X																										
	87	VU24			3	3		X						2				1			3				2								
	89	VU12				3			X					1								3											
	242	EBS26						2		X																							
PROJECT 2	46			1		2					X	1	3											1									
	155	VU43										X	2	1																			
	19	64775											X			2	3																
	9	EBS04						1				1		X	2						1	2		1									
	24	VU03				2	3				2		3	3	X	3	2			3	1												
	12	EBS03											2			X		2															
	138	AIU		3		2	1	3						1			X	3	1		3			3	3		1						
	10	EBS02														2	3	X	2														
	88	VU21																2	X														
PROJECT 3	162	VU12	2	3	2	2		2												X	3				2								
	169		1	3		3	3	3		3			2	2				3	1	3	X	3			2				1				
	123	GA107	3	3	3	3	3	2	3	3		3	2	3	3	3	3	3		3	3	X	2	3	3		1						
	122	VU23							3													2	X										
	145	VU12	1			3																3		X									
	61	VU14A		1																	1				X								
	334	EWS39																					1			X							
PROJECT 4	100	VU19		1													1										X						
	185	VU16																										X					
	377	EWS39																											X				
	176	IRST.1																												X			
	148	EBS21																													X		
	212	EWS39																														X	
	241																																X

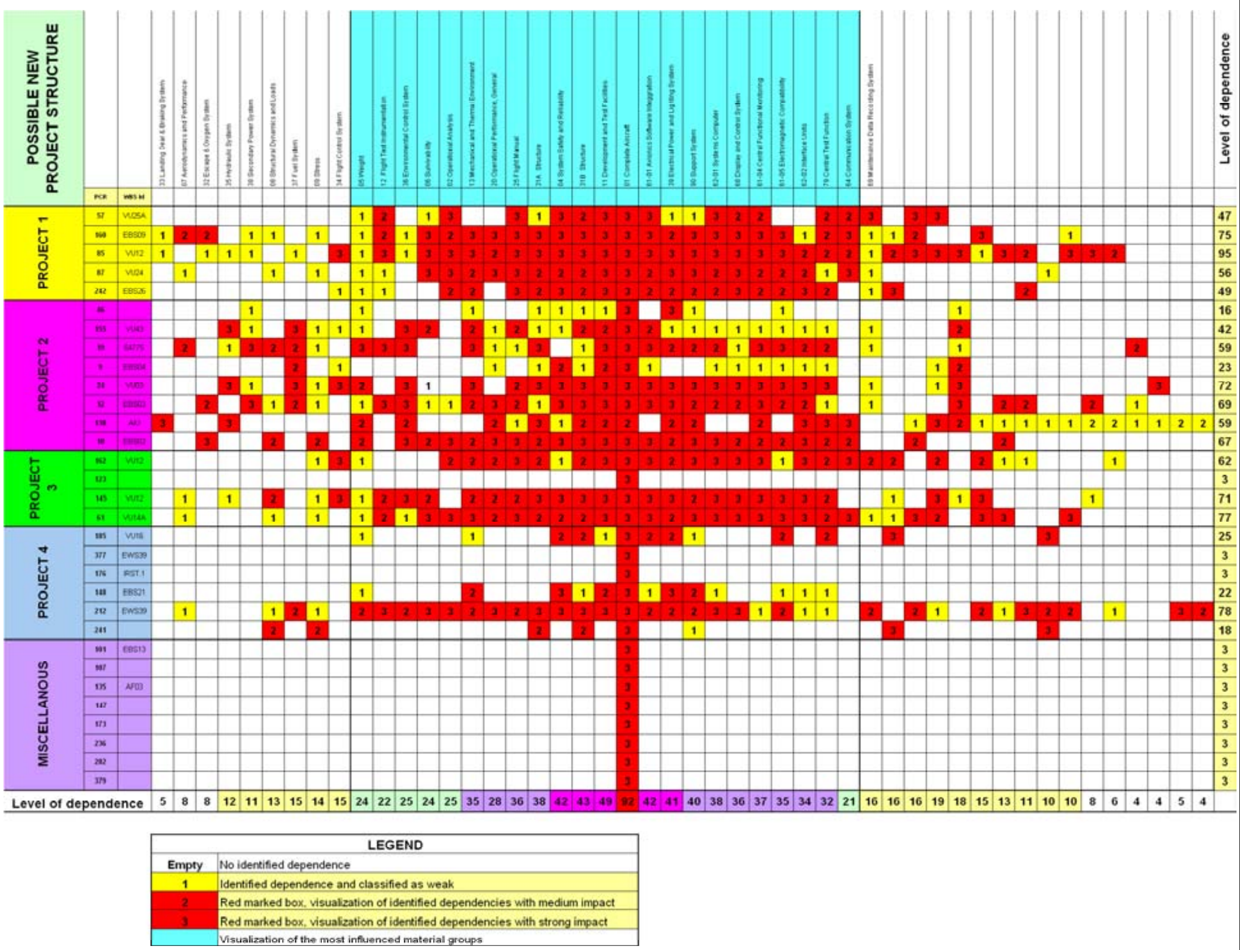
Legend	
X	Intersection of row - column. Diagonal line of no interest.
1	Identified dependence, weak impact
2	Red marked box, visualization of identified dependencies with medium impact
3	Red marked box, visualization of identified dependencies with strong impact
(yellow)	Possible new project 1
(magenta)	Possible new project 2
(green)	Possible new project 3
(blue)	Possible new project 4

obtain clusters of tasks forming a multiproject structure. This is a delicate task and no existing algorithms can be used since the complexity in making these decisions is influenced by many aspects, such as the workload contained in each of the identified POIs, the technical complexity in each task, which may demand special efforts by a technical department, special attention according to airworthiness directions and certification by persons in the basic organization.

Therefore, Figure 10 shows only one of several possible solutions. In this case, we indicate that all 30 tasks were reorganized in four major projects on the basis of the relationship among engineering tasks. We can also see that no matter how we organize these tasks in projects, some POIs containing important relations will always be left outside a particular project. This can be seen as the interface between projects, which must be taken care of through some form of coordination of people or integration of their tasks inbetween projects.

As we have noted earlier in this paper, project organization and function-oriented basic organization co-exist. The problem is to understand the relations between projects and basic organization in order to enhance the coordination of people in their project work and the work carried out in the basic organization. In complex projects such as aircraft development, it is difficult to achieve full-time participation of engineers in each of the identified projects. Too many activities are in progress simultaneously to enable collocation of full-timers other than in a number of special cases. In most cases, there will be part-timers joining and leaving different projects depending on the need for their specific knowledge. The level of individual specialization is very high and prevents the use of engineers in broader knowledge areas.

Figure 11 : DSM-analysis, Batch XX, Task - Material Group, FINAL



Step 2 – Coordination of the multiproject structure – basic organization

Figure 11 shows the second DSM analysis. This figure focuses on identification and evaluation of relations between proposed new project structure and the prevailing basic functional organization. From this figure, we can see that there are a number of functional departments that play a more central role than others. These departments could be given a special coordination role between functional departments and proposed projects.

In Figure 11, an extra project cluster is introduced, labeled "Miscellaneous". This cluster is not present in Figure 10 since the first DSM matrix focused only on identifying the new project structure. In the formation of projects, some business tasks were omitted from Figure 10 because they were considered part of a more global coordination activity oriented towards projects. The business tasks placed in the "Miscellaneous" group show very little relations towards the basic organizational structure, but from the management point of view it is difficult to handle so many business tasks on their own. Clustering these in the same group made it easy to identify and allocate a project manager to each of these projects and to let management focus on a smaller but more integrated project structure.

Figure 12: Holistic Approach to Multiproject Environment

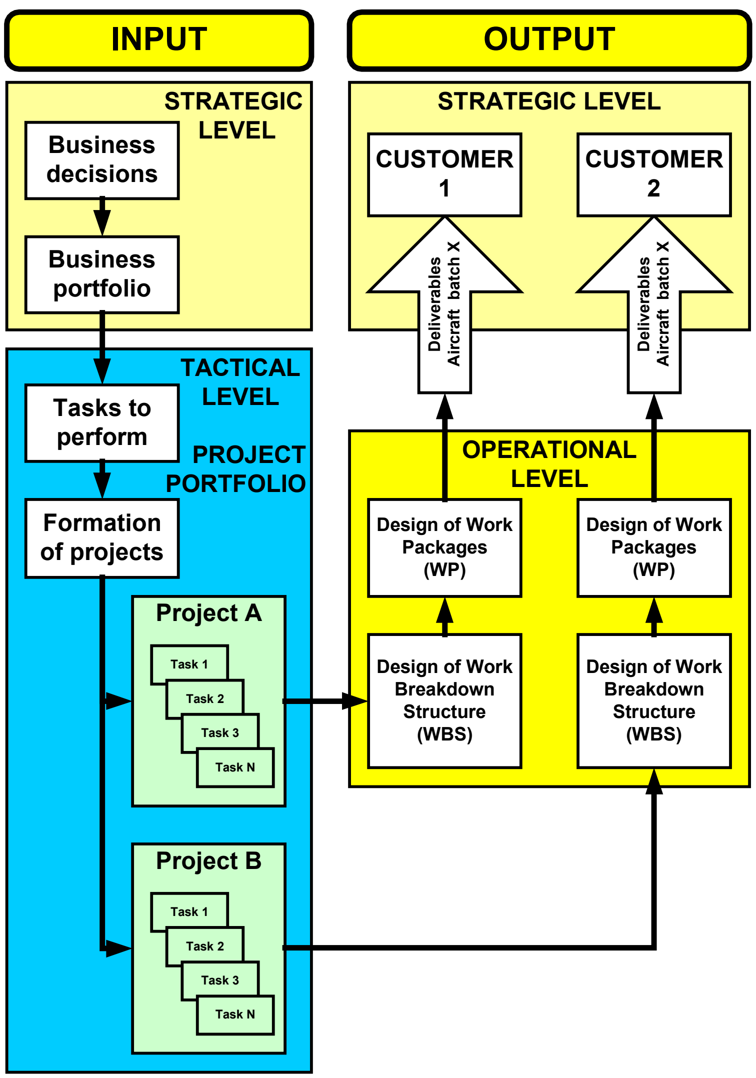


Figure 12 shows how we tried to grasp the problem of managing a multiproject structure from the strategic level to the tactical level and the operational level, even if our focus was on the transformation of the strategic level to the tactical level. The starting point consisted of the strategic decisions that create a strategic business portfolio. When business decisions have been made, the organization needs to be prepared to take care of the deliveries. The traditional approach at Saab has been to organize business decisions according to the logic of functional departments. This created a situation that was difficult to manage, since the total number of projects was almost as great as the number of tasks conducted in within the projects.

Our approach shows that giving consideration to relations and dependencies among business decisions and engineering tasks can transform the logic of business to the logic of projects. However, the logic of the functional basic organization cannot be overlooked and neglected. In order to assure that attention is paid to the relations between the new proposed project structure and the functional basic organization, a special coordination mechanism needs to be developed. Figure 11 shows that different projects have different patterns of relations towards the basic functional structure and that individual solutions need to be developed for each of these new projects.

On the tactical level, a project portfolio comprises the total number of existing projects consisting of a series of engineering tasks that originate from different business decisions. It is necessary to understand this because the customer may buy a “new color display and NATO weapon pylons, etc”. However, the customer does not want to receive these items in special boxes, but in special aircraft batches meeting the delivery schedule, as well as complete aircraft according to specifications. To assure that aircraft are delivered according to the strategic agreements, business decisions, and engineering tasks have to be analyzed and organized according to the delivery logic and not to the logic of business decisions. Therefore, in the new proposed project structure each project may contain tasks from different business decisions, or occasions, encompassing different engineering tasks. The result of this is an integrated project portfolio structure that is customer- and business-oriented according to the delivery schedule.

Discussion

This paper deals with one of the most complex products that exist today, the JAS 39 Gripen. It is important to study situations characterized by high complexity such as product development of aircraft, since other companies in other business areas or industries seem to be shifting in the same direction of complexity, such as the medical industry, information processing, the nuclear power industry, the communication and transportation industry, etc.

In this paper, we have introduced DSM analysis in order to handle complexity on two organizational levels, the strategic and the tactical. What is not covered due to the time restrictions of the project is the extension of the findings on the tactical level to further design of each project’s WBS and WP structures, enabling the logic of relation analysis to be completely followed up and developed as intended. We have tried to show how DSM analysis can be used to take a standpoint in the business portfolio and on the basis of a relation’s analysis in order to design a project organization. The results show that what in the first place was a series of business decisions and engineering tasks conducted on the functional basis could be organized in projects following the business logic and deliveries to the customer. However, we also show that the project structure and the prevailing basic organization cannot be regarded as contradictory and mutually exclusive. Instead of competing with each other, these dual structures need to find a balance of focus between the persistent based and the temporary in dynamic structures, consciously adapting to new businesses and new engineering tasks when they are introduced. In order to be able to cope with changes, the development of new technology, increased competition, changes in customer preferences in the market, and increased demands on shorter lead times and costs, and improved technical quality in product development, companies need to develop dynamic structures, continuously changing and rearranging old structures into new structures with a temporary project-driven organization.

There is an incongruity between these two organizational settings, the cross-functional temporary based project and the function-oriented basic structure. One type of logic governs the long-term functional-oriented basic structure, which focuses on developing basic technology and knowledge on the edge of, and even beyond, the present technological level.

The short-term, task-oriented cross-functional team is based more on the participation of the people involved in cross-functionally composed teams. The team-oriented work creates an arena that influences daily work in order to achieve and maintain cross-functional collaboration. This corporate development process, implying a continual restructuring, has to involve all the hierarchical levels of a corporation, vertical as well as horizontal and lateral, in multi-level, cross-functional teams. Creating such dynamic structures can be described in metaphors as an ameba, chaos or the fractal factory, which are all continuously changing, incorporating every horizontal and vertical activity and level, supporting lively communication between all participants (Warnecke, 1993).

A complex system consists of parts that interact and are dependent to some extent. Simon (1957, p. 87, 1969, p. 73) argues that hierarchy is an organizing principle of complex systems which are composed of interrelated subsystems in turn having their own subsystems, and so on. In this approach, hierarchy refers to the decomposition of a complex system into a structured ordering of sets of subsystems, a partitioning into relationships that collectively define the parts of a complete system. Once the tasks are separated, they must be placed in blocks or arranged in such a way as to reduce the problem-solving dependence, or simply affect the way in which problem-solving is distributed among tasks and people. However, these points of dependence first have to be identified and handled according to their impact and the probability and plausibility of their appearance. The term "hierarchy" is used by Simon (1962, 1969) in a more general manner than is usual in organizational economics and organizational theory (e.g. Williamson, 1975), where hierarchy typically denotes subordination to an authority -based relationship.

> *The division of labor is quite as important in organizing decision-making as in organizing production, but what is being divided is different in the two cases. From the information-processing point of view, the division of labor means factoring the total system of decisions that need to be made into relatively independent subsystems, each one of which can be designed with only minimal concern for its interaction with others. The division is necessary because the processors that are available to organizations, whether humans or computers, are very limited in their processing capacity in comparison with the magnitude of the decision problems that organizations face. The number of alternatives that can be considered, the intricacies of the chains of consequences that can be traced — all these are severely restricted by the limited capacities of the available processors (Simon, 1957, p. 293).*

From the point of view that product development, and projects in general, is partitioned into smaller tasks, the emerging boundaries between these tasks may cause problems in the problem-solving process of managing dependencies across boundaries and between tasks.

Decomposition of a product may sound like rational, objective, and engineering- and scientific-oriented work. However, traditions and tacit knowledge are embedded in the process of decomposition.

> *We have always designed aircraft bodies by dividing them into a series of cylindrical sections and assigning each section to a different task group. No one now at the company has thought about why we do this or whether it currently makes sense from any point of view. It is just the way we do it (quotation in von Hippel, 1990, p. 410.)*

This quotation indicates the impact of traditions, but also emphasizes that the technical logic and the architecture of a product have considerable impact on the way the process of decomposition and integration can be conducted. The product itself may hamper the degrees of freedom. In the case of aircraft development, the impact of product architecture is strong. This is emphasized by the method of manufacturing the aircraft: low-volume series and a low level of automation in manufacturing.

No matter how a product is partitioned, we must understand the answer to the question of why it has been partitioned in one way or another. There may be tacit and salient knowledge interlaced with extensive and important experience that it is vital not to ruin. The complexity in partitioning a complex product such as an aircraft is extremely high, and many different aspects must be considered in the partitioning process. What may look reasonable from one approach may be filled with problems from other approach. It is also important to understand the partitioning logic at different levels of the product architecture. Sometimes, especially in the aircraft industry, the partitioning logic may be due to airworthiness directives or demands of authorities, not only tradition and departmental logic.

The impact of partitioning is a question of mastering the dependencies between tasks. This paper shows that there are no final answers as to how a complex product can be partitioned and clustered in manageable elements or chunks, sometimes labeled as projects. The traditional way has been to follow the technical logic of the aircraft and the logic of the basic functional organization. In this paper, we show that another logic may be used following a combination of the business logic and the technical logic of engineering tasks originating from businesses. Whether this is the ultimate way of partitioning and clustering remains to be seen in future research activities.

From DSM Figures 10 and 11, we can see that no matter how we partition a complex task into subelements, tasks, components or people, there will be areas between clusters containing important relations and dependencies. This means that the attempt to design clear-cut interfaces is doomed to fail. Instead, we should orient ourselves towards designing structures and processes that can help management and engineers grasp these areas in between clusters in order to prevent important information being lost “between desks”, so to speak. How this can be done is not obvious.

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