Data gathering for Schedule Risk Analysis

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Summary

Projects involve numerous risks over their lifetime. All these risks will aggregate to scheduling and subsequently to financial risk. On this aggregated level best practices state that the project manager should manage scheduling risks by identifying, analyzing and assessing their impact on the project objective.

The objective of this paper is to outline a company tailored model for schedule risk analysis by researching recommended best practices and of studying a scheduling process at the company.

Findings from the research include proposed structures for generating the project Work Breakdown Structure through scope management and guidelines for developing a robust schedule.

The result from the research is an outline model involving two main processes; Scope management and Time management. These processes will provide for the company to analyze schedule risks at any level in a project hierarchy.
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1 Introduction

1.1 Background

All projects involve a level of uncertainty defined as risks with positive or negative outcomes (Kendrick, 2009). Positive risks are commonly referred to as opportunities and negative risks as threats (Standards Australia/Standards New Zealand, 2004). Risks will always be associated with the project’s schedule and cost and must be managed efficiently to provide for project success (Dobson & Dobson, 2012). Efficient risk management draws benefits from opportunities and minimizes the impact of threats (Kendrick, 2009).

Harvard Business Review Press (2011) states that a business case supports organizations in deciding on initiation of a project based on the relation between the project’s threats and opportunities. Organizations with high awareness of project risks will have a sound base for decision by assessing the possible impacts on schedule and cost.

Rufran Frago (2013) states that a prerequisite for a qualitative schedule risk analysis is that the risk data is of high quality.

This paper analyzes best practice for scheduling and for risk data gathering, observes a project schedule updating process and proposes a data gathering model. The proposed model will provide for all project management levels at the company to perform risk analysis on schedules. This will enable the managers to identify risks early, understand their consequences and to plan for actions to manage them.

This paper will not discuss scenario analysis which is another method for estimating the probability for achieving the project objective. This topic is evaluated by another project at the studied company.

Conclusions drawn from the researched literature can be summarized as; the final outcome of the project will be available only after the project has been closed but it can often be predicted by efficient risk management.

1.2 Goal

The goal set out for this research is to outline a company-tailored model for gathering input data to schedule risk analyses. To achieve this, three research questions are raised:
Q: How do successful organizations schedule their project?

Q: How do successful organizations gather data for schedule risk analysis?

Q: How can the company’s current processes be used or adapted to gather quality data for schedule risk analysis?

A prerequisite for answering these questions is that “success” is defined in the context of this paper’s scope; data gathering for schedule risk analysis.

In the book *Managing Stakeholder Expectations for Project Success: A Knowledge Integration Framework and Value Focused Approach* Ori Schibi (2014) defines three layers of success; Project objectives, Business objectives and Project organization. Schibi explains these as follows:

- The project objectives focus on scope, time, perceived quality and the project’s deliverables.
- The business objectives relates to the product and how it adds value to the organization and how it benefits the customer.
- The Project organization layer measures how the project is managed; the team’s performance, lessons learned and conflict management. Further, at this layer it is examined if the business success and project success conform to each other.

Schibi’s definition for the success of project objective is in line with Harold Kerzner’s definition in the book *Advanced Project Management: Best Practices on Implementation, Second Edition* (Kerzner, 2004). Kerzner measures success by primarily delivering on time, within cost and at desired quality. Kerzner lists secondary success factors as customer acceptance and that the customer is willing to be used as reference.

Based on Schibi’s and Kerzner’s definitions, this paper defines success as delivering the project scope within the defined timeframe.
1.3 Scope

1.3.1 In scope
The scope for this paper is to outline a process model for gathering data as input to quantitative schedule risk analysis (SRA) using Monte Carlo simulation techniques. The focus of this paper is the data gathering and scheduling processes used as input to Monte Carlo simulations.

1.3.2 Out of scope
The paper will not discuss the Monte Carlo simulation technique, nor its underlying statistics. These topics are covered in detail in other literature.

This paper will not discuss scenario analysis which is another method for estimating the probability for achieving the project objective. This topic is evaluated by another project at the studied company.

1.4 Method
This paper’s goal is to outline a company-tailored model for gathering input data to schedule risk analyses. To achieve this, and to answer the research questions, the following steps will be performed:

- Review existing literature on the topic of schedule risk analysis.
- Define the operational context for where schedule risk analysis will be conducted.
- Perform a case study of a project.
- Outline a model for data gathering as input to Monte Carlo simulations tailored to the company project processes.

1.5 Limitations
This research is limited by several factors. Firstly, the research is not sponsored by the studied company which imposes access to resources in terms of personnel, data and tools.
Secondly, the accessible project-specific data is classified and must therefore be manipulated to protect company integrity.
Finally, the case study includes only one project. This project was selected under the assumption that it can be considered to be a typical project representable for illustrating the current company process.
2 Methodology

The goal for this research is to outline a company-tailored model for gathering input data to schedule risk analyses. The first step is to review existing literature on the topic of schedule risk analysis with the purpose of defining recommended best practices for schedule creation and for data collection. Second, the company’s processes are analyzed to define the operational context for schedule risk analyses. Third, a case study of an ongoing project is performed to provide for evaluation of how the company’s processes are used in practice. This is followed by an analysis and discussion on the literature review and the case study to define company’s application of the recommended best practices. Finally, a model is outlined based on the outcomes from the analysis and discussion.

This section will provide detailed information on the strategies selected for each research step.

2.1 Literature research

The literature research will take an inductive approach to provide the information required for answering the first two research questions; “How do successful organizations schedule their project?” and “How do successful organizations gather data for schedule risk analysis?”. First, the research will gather data on the topics of scheduling and data collection in the context of schedule risk analysis. Next, the data will be analyzed for patterns which will subsequently be used to develop a theory of what can be considered best practices (Blackstone, 2012).

![Figure 2-1 Inductive research. Adapted from (Blackstone, 2012)](image)

To provide information for answering the third research question, “How can the Company’s current processes be used or adapted to gather quality data for schedule risk analysis?” the company’s processes will be examined. This will take an inductive case study approach to data analysis of a single source – the company’s processes.
2.2 Case study

In an attempt to provide further information for answering the question “How can the Company’s current processes be used or adapted to gather quality data for schedule risk analysis?” an empirical study of a project will be performed. The case study will be a single-case-study which is relevant for when the case can be representative or typical (Yin, 2007). Specifically, the case study will take an inductive approach to develop a theoretical model which can be tested (Blackstone, 2012).

2.3 Analysis and discussion

Findings from the literature research and the case study will be analyzed, discussed and summarized and used as input to the schedule risk analysis model tailored to the company.

The literature research is valid for any project organization and the discussion and analysis statements are objective.

The case study, however, is only valid for the studied company as this paper’s scope is to outline a model tailored to the specific company. Other organizations may use the findings from the case study as data to support quantitative data collection.

2.4 Schedule Risk Analysis Model

The proposed outline model for schedule risk analysis will evolve from the literature research and the case study and is only valid for the studied company.

3 Data and literature research

The purpose of analyzing the schedule risks is to quantify the confidence level of achieving the project’s milestones. To achieve this three inputs are required; a schedule, its associated risks and an analysis model (Company, 2014).

As the scope of this study is to define a model for data gathering as input for schedule risk analyses the literature research begins with describing the input to scheduling; namely the WBS (Work Breakdown Structure). Next, the research focuses on scheduling best practices which will answer the first research question; “How do successful organizations schedule their project?” This is followed by answering the second research question “How do successful organizations gather data for schedule risk
analysis?” by studying existing literature describing data collection techniques. Finally, the company’s current processes are described.

### 3.1 WBS

In the PMBOK Guide (Project Management Institute, 2013) the “Create WBS” process is included in the “Project Scope Management” and thus not a scheduling activity. The PMBOK guide defines the WBS as a *hierarchical decomposition of the total scope of work to be carried out by the project team to accomplish the project objectives and create the required deliverables.*

In the book *20:20 Project Management: How to Deliver on Time, on Budget and on Spec* Tony Marks (2012) defines the WBS as a *hierarchical structure that allows a project to be divided by levels into discrete groups for programming, cost planning and control purposes.*

Gregory T. Haugan, author of the book *Project Planning and Scheduling* (2002), states that the WBS is *the key tool in the planning phase to assist in work definition and to provide the framework for the plans and schedules.* This statement is supported by Kerzner (2009) who states that the *WBS is the single most important element because it provides a common framework from which (...) planning can be performed.* A well-defined WBS describes the total project scope subdivided into smaller, more manageable parts (Buchtik, 2013). There are two types of WBS components:

- **Level of Effort:** *Support-type activity (e.g., seller or customer liaison, project cost accounting, project management, etc.) which does not produce definitive end products. It is generally characterized by a uniform rate of work performance over a period of time determined by the activities supported.* (Project Management Institute, 2006)

- **Discrete:** *an end product, service, or result that can be directly planned and measured. It’s a tangible, definite, separate, distinct deliverable.* (Buchtik, 2013)

Buchtik also provides definitions to the terms used in the WBS. She states that a WBS component with attributes (responsibility, cost etc.) are called a WBS element. Further she defines Work packages as the lowest level WBS component and that they shall include the scheduled activities and milestones required completing the work package delivery.
One core characteristic of the WBS is the 100%-rule (Haugan, 2002) which states that 100% of the work in a parent element shall be represented by the sum of all the work in the child elements. Buchtic (2013) highlights that it is important that the sum of all the work must add up to 100% - no more, no less. Any work above 100% falls outside the project scope and each work package must add up to 100% of its parent (Project Management Institute, 2006).

According to Buchtic (2013) there are a number of common misconceptions on what a WBS is:

- A WBS is not an exhaustive list of the work to be performed in the project.
- A WBS is not a schedule or a listing of the chronological sequence of activities
- A WBS is not a project plan
- A WBS is not an organizational chart
- A WBS cannot be changed without formal configuration management

The Practice Standard for Work Breakdown Structures (Project Management Institute, 2006) lists the following uses for the WBS:

- To define the project scope
- To provide a framework for status and progress reporting
• To facilitate communication to stakeholders
• As input to other project management processes and deliverables

One of these deliverables is scheduling (Project Management Institute, 2006) which is described below.

### 3.2 Scheduling

The PMBOK Guide (Project Management Institute, 2013) defines the Project schedule as an *output of a schedule model that presents linked activities with planned dates, durations, milestones, and resources.*

Meredith & Mantel's (2012) definition of a schedule is that a *schedule is the conversion of a project work breakdown structure (WBS) into an operating timetable.*

Rufran Frago provides guidelines to preparation for schedule (quantitative) risk analysis in his paper *How to Prepare for Schedule Quantitative Risk Analysis* (Frago, 2013). He states that the project schedule is started by one single start milestone, a trigger. This trigger is the initiator of the subsequent activities leading to the completed project objective, the end milestone.

Further, Frago states that the precedence diagram in Figure 3-2 illustrates how the start milestone precedes the initial activities followed by additional activities. Each activity is a successor to one or more preceding activities creating a network. Over the duration of the project the activity network expands and recedes to completion of the final objective.
Three main quality attributes can be allotted to an ideal schedule; it has no fixed or compulsory dates, all activities have predecessors and successors and it has defined dependencies (Frago, 2013).

### 3.2.1 Constraints

Frago (2013) also states that a fixed or compulsory date such as “Must start on” or “Must finish on” implies that the date has a one-hundred percent certainty of being met. This is rarely true and if the schedule contains constraints they should be agreed by all stakeholders. Soft constraints; “Start no earlier than” or “Finish no later than”, should be avoided or minimized. Soft constraints will impact critical path calculations (Frago, 2013).

### 3.2.2 Activities

Haugan (2002) states that activities are below the WBS work package level. In the activities the actual work is performed and network planning is accomplished. Haugan (2002) concludes that *Activities represent action and are normally stated in verb/adjective/noun form.*
Activities define what needs to be performed to complete the project and should have the following characteristics (Project Management Institute, 2011):

- it is a measurable and discrete element of work within the project scope
- the responsibility for performance is assigned to one single person
- its description is unambiguous and unique and leaves no room for confusion
- it has a predecessor and successor

Taylor (2008) writes that each task (activity) must be connected to some predecessor and successor. These can be an activity/task or an event.

### 3.2.3 Critical Path

In the book *Project Management for Flat Organizations: Cost Effective Steps to Achieving Successful Results* Laura Dallas Burford (2013) states that the critical path is the longest path of activities required to complete the project. There are different techniques for defining the critical path, the most common being the Critical Path Method (CPM). CPM is a traditional and well accepted method for developing the logic of the project and for the management of activities on a daily basis. However, Frago (2013) states that the CPM schedule requires that all activities are started “As soon as possible” and that the actual activity durations are identical to the estimates. Since projects never fully go according to plan, the CPM is not an end result but an important input to a quantified risk assessment (Hulett, 2007).

### 3.2.4 Dependencies

Laura Dallas Burford (2013) writes that dependencies in the activity network are illustrated by logical links between activities. There are four relational links between activities; Finish-to-start (FS), Start-to-start (SS), finish-to-finish (FF) and Start-to-finish (SF).
PMI’s Practice Standard for scheduling (Project Management Institute, 2011) recommends using FS relations exclusively. *If other types of relationships are used, they should be used sparingly and with a full understanding of how the relationships have been implemented (...). Ideally, the sequence of all activities will be defined in such a way that the start of every activity has a logical relationship from a predecessor and the finish of every activity has a logical relationship to a successor*” (Project Management Institute, 2011). This approach will provide the scheduler an easier view of the schedule. Frago (2013) states that an FF dependency implies that the finish of the two activities must be coordinated. Similarly, SF dependencies require the start of the predecessor to be coordinated with the finish of the successor. Frago (2013) recommends avoiding FF and SF dependencies.

For the schedule to provide for a successful risk analysis the dependencies should show all important parallel paths and merge points considering the “Merge Bias” (Hulett, 2007).
In the white paper *Schedule Risk Analysis Simplified* Hulett (2007) explains that merge bias occurs when parallel paths converge and their probability distributions overlap. The result is a decreased probability for meeting the milestone at the convergent point. If there are several converging paths the probability for delay is further magnified (Hulett, 2007).

### 3.2.5 Lag

Dependency links can be complemented with time-lag defining the time span between activities. In the article “The Great Negative Lag Debate” (Douglas, Calvey, McDonald, & Winter, 2006) the authors defines lag as the number of time units from the start or finish of an activity to the start or finish of its successor. Positive lag denotes that the succeeding activity must start at a given time after its predecessor. Similarly, negative lag denotes that the succeeding activity must start before the completion of its predecessor. Douglas, Calvey, McDonald, & Winter (2006) discuss the pros and cons of negative lags. Their argument for negative lag is that they provide “a reasonable method to create workable schedules.” Further, the authors argue that the major problem with negative lag is that they lack transparency and that they “have to be translated to the user of the schedule, by the scheduler.” Frago (2013) states that negative lag on a FS dependency can result in critical path calculation error when the successor tries to start before the predecessor. On a SS dependency negative lag can be replaced by a positive lag as illustrated in Figure 3-5. This makes the schedule easier to understand (Frago, 2013).
3.2.6 Resources
Resource estimates include defining the personnel, material, equipment and infrastructure required to complete the activity (Burford, 2013). According to the PMBOK (Project Management Institute, 2013) resource estimating should precede the duration estimate. However, these two activities are sometimes performed together as one resource category can render different durations; a senior engineer is more likely to perform an activity faster than a junior engineer (Burford, 2013). As resourcing can affect the project’s critical path this process should not be neglected (Project Management Institute, 2011). Estimated personnel resources (staff) are expressed in Estimated Level Of Effort (LOEE) for each activity (Burford, 2013).

3.2.7 Duration estimates
An activity’s duration defines how much calendar time the activity will consume (Burford, 2013). According to PMI, good practice recommends defining the activity first, then tying it logically into the overall schedule sequence and then focusing on activity resources and duration (Project Management Institute, 2011).

3.2.8 Analysis
The duration estimates provide the uncertainty that the schedule risk analysis aims at evaluating (Hulett, 2007). Chapman and Ward (2011) list two different planning processes that can be used to identify the uncertainties to an appropriate level of detail; bottom-up and top-down. According to the authors most traditional project planning is bottom up. Harvey Maylor (2003) states that the most widely accepted technique for quantifying uncertainties is PERT (Program Evaluation and Review Technique) which deals with the likelihood that single value estimates will have an associated level of error. PERT uses three-point estimates for each activity defined as follows by Maylor (2003):
• Optimistic (o) – duration under ideal conditions
• Most likely (m) – duration under “normal” conditions
• Pessimistic (p) – duration if the majority of things that could go wrong did go wrong

This data is used to calculate the expected time for each activity using the formula

\[
\text{expected time} = \frac{o + 4m + p}{6}
\]

Next, the activity’s variance and standard deviation (\(\sigma\)) is calculated as follows:

\[
\text{Variance of activity time} = \left(\frac{p - o}{6}\right)^2
\]

\[
\sigma = \sqrt{\text{Variance of activity time}} = \frac{p - o}{6}
\]

The next step is to calculate the value \(z\) which will be used to determine the probability of meeting a desired date, the specified time:

\[
z = \frac{\text{specified time} - \text{expected time}}{\sigma}
\]

The probability corresponding to the \(z\)-value is found in a normal distribution table. This is the probability that the activity will meet the specified time (Maylor, 2003).

According to Dobson & Dobson (2012) **most operating project managers who need to perform schedule risk analysis have switched from PERT to the Monte Carlo simulation technique.** Similar to PERT, Monte Carlo also uses three-point estimates in addition to probability distributions as input to simulation of a project schedule. Monte Carlo then simulates all activities’ ranges of durations thousands of times. This provides distributions showing how often the project is statistically finished on a given date (Dobson & Dobson, 2012).

Chapman & Ward (2011) also writes that a top-down method of estimating is the successive calculus, or Lichtenberg Principle, where a brainstorming session identifies all possible uncertainties in a project. These are then grouped and the main sources of uncertainty are identified. The largest sources are further decomposed until an appropriate level of detail is achieved (Chapman & Ward, 2011).
Laura Dallas Burford (2013) recommends using estimates of duration (D) and Estimated Level of Effort (LOEE) to determine the Required Level of Effort (LOER) for activities by calculating

\[ \text{LOER} = \frac{\text{LOEE}}{D} \]

where the LOER represents the required average number of hours to complete the task in the number of days specified by the task duration (Burford, 2013).

Depending on what the constraining factor is Burford (2013) list three additional equations that can be used to determine the time and resources required to complete the activity. These equations consider the availability of resources – the Level of Effort Available (LOEA) (Burford, 2013):

\[ \text{Required Staff} = \frac{\text{LOER}}{\text{LOEA}} \]

\[ \text{LOEA} = \frac{\text{LOER}}{\text{Staff}} \]

\[ D = \frac{\text{LOEE}}{\text{Staff} \times \text{LOEA}} \]

### 3.3 Risk data collection techniques

PMI (Project Management Institute, 2013) defines risk as “An uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives."


*In projects, a risk can be almost any uncertain event associated with the work.*

The confidence level is dependent on the quality of the input data provided in estimates. Literature\(^1\) suggests that several methods for collecting data are combined. The PMBOK (Project Management Institute, 2013) lists the following:

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\(^1\) (Kendrick, 2009), (Chapman & Ward, 2011) and (Raydugin, 2013)
**Interviews**. The typical interview involves asking prepared and/or spontaneous questions to one or more interviewees. Interviews are useful in identifying experience from experts, sponsors and other executives (Project Management Institute, 2013).

**Focus Groups**. Focus group discussions can complement surveys by adding insight to the range of the group’s opinions and ideas (ODI, 2009). Judith Langer (2006) writes that the usual focus group ideally gathers six to eight participants for discussions on a given topic guided by a moderator. The moderator’s ability to plan, lead and document the discussions will determine the output quality, or as Langer (2006) states: *They have to be good researchers and good project managers*. As this type of discussion involves the groups’ individual’s opinion they cannot represent a general population. Langer (2006) concludes that focus groups will not give all the answers, but they should provide good insight.

**Facilitated Workshops**. Facilitated Workshops are a specialized type of meeting, with a clear objective (product), a set of people (participants) who are chosen and empowered to produce the product and an independent person (facilitator) to enable the effective achievement of the objective (Dynamic Systems Development Method Limited, u.d.).

**Group Creativity Techniques**. There are a few group activities that can be used to identify project scheduling requirements in facilitated workshops. Marian Haus, PMP, propose starting with mind mapping and brainstorming followed by affinity diagramming, nominal group technique and closing the process by several rounds of Delphi technique feedback (Haus, 2012).

**Group Decision-Making Techniques**: A group’s decision making can be reached by:

- **Unanimity**: the group reaches a consensus decision.
- **Majority**: the group reaches a decision supported by the majority of the members.
- **Plurality**: the largest block in the group decides.
- **Dictatorship/authority**: one person makes the decision.

Sam Kaner (2007) identifies four values the facilitator needs to provide to the group for establishing sustainable agreements; encourage *full participation*, promotes *mutual*
understanding, foster inclusive solutions and cultivate shared responsibility. Kaner (2007) concludes that adhering to these values produces stronger agreements.

Questionnaires and Surveys\(^2\) can provide information from a large population and where the respondents are geographically dispersed. Ian Brace (2013) defines a questionnaire as a \textit{structured interview in which each subject or respondent is asked a series of questions according to a prepared and fixed interviewing.}

Observations, inspection, benchmarking and document analysis\(^4\) provides data by assessing past or ongoing work.

### 3.4 Company processes

The company’s processes for scheduling and risk management are mandated by the corporate Lifecycle management (LCM) framework. Within this framework handbooks provide information on managing schedules and risks. This section provides a description of the company tailored processes applicable to schedule risk analysis (Company, 2014).

#### 3.4.1 Scheduling

The scheduling process is included in the Project Planning process whose ownership lies with the head of Project planning. Its purpose is to create a master time schedule for the project and to plan the work in detail. Inputs to this process is a project specification developed by the bid manager/project manager. The scheduling process includes “Creating master schedule”, “Create detail schedules” and “Document plan”. In projects, the scheduling process is managed by the Project planners. Participants include all managers reporting to the project manager and sub-managers as applicable.

\(^4\) (Project Management Institute, 2013)
3 Data and literature research

![Diagram](image)

**Figure 3-6 Project Planning process with the scheduling process (green)**

The process **Define Planning Task** precedes and is input to the scheduling processes.

![Diagram](image)

**Figure 3-7 Process "Define planning"**

**Analyze project prerequisites** involves defining the project goals, definition, scope and the company’s continuity plans. General applicable conditions are evaluated for threats and opportunities as, preferably, group sessions. A reference project shall be defined and used for deriving experiences.

In the **Define structure for project scope** process the project WBS is created and, if
required, an additional WBS used for external communication is created. These structures are based on a template WBS with associate dictionary and a base-structure of the platform's subsystems. This is performed by the bid manager/project manager, project planner and the project controller.

Next, the **Allocate responsibility** process aims at defining the project organization and to allocate responsibilities for the WBS elements. The contributors to this process are the bid manager/project manager, technical project manager and the ILS manager. Finally, the **Allocate Target Cost** process breaks down the overhead target cost to the subsystems setting a cost framework for the work packages.

![Figure 3-8 Process "Create Master Schedule"](image)

The **Creating Master Schedule** process begins with **identifying activities** using inputs from visual planning (KIVP)\(^5\), the LCM framework and an instruction for project planning. The purpose of this process step is to break down the main project objective into large work packages with defined responsibility and entry/exit criteria.

Next, the process step **Identify dependencies** focus on defining the logic between work packages.

This is followed by **Creating outline schedule** where the work packages are scheduled considering relevant calendars and the critical path is evaluated. Unresolved scheduling conflicts can in exceptional cases be added to the risk list.

Next, **Identifying/defining system and subsystem milestones** is iterated to derive milestones for configuration management baselines.

The **Creating Master Schedule** process is finalized by **Communicating the plan** to stakeholders.

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\(^5\) KIVP is an acronym for Knowledge Innovation, Visual Planning - a method for working with deviations and issues breakdown with the purpose of having a corrective and learning organization, and by visualizing the goals of the project broken into deliveries and visualized on a visual planning board.
With the Master schedule communicated the **Create Detail plans** process is initiated by the process step **Define detail plan**. This process step uses an instruction for iteration planning and assessment and is carried out by sub-system managers, the quality manager and procurement manager. Process outputs are verifiable goals for the immediate detail plan phases and preliminary verifiable goals for future (long term) phases.

Next, the **Identify activities** phase aims at breaking down work packages into activities. Supporting documents for this phase are instructions for iteration planning and assessment, baselines and for project planning.

In the **Detail planning** process step a logical network of the identified activities is to be created, durations for the activities are defined and the critical path is analyzed. This phase uses KIVP, instruction for project safety planning in addition to the project planning instruction.

The final process step in the **Create Detail plans** process is **Allocate resources**. Its purpose is to allocate individuals to the short term activities and to allocate personnel categories to the long term activities. In this process step Primavera© is used for resource allocation and for budgeting activity costs. A template for work package description is used to define purpose, input, and output and target cost. The detail plan and resource allocation are to be agreed by line managers and the project manager via a "sign-off" based on the Primavera© plan.
At this stage the **Document plan** process follows where an **Analysis of feasibility** is performed. Data from the Primavera© system is analyzed with the support of a feasibility checklist and the project planning instruction and scenarios are simulated. This process step is performed by the project manager, project planner, technical project manager, ILS (Integrated Logistic Support) manager and the project controller.

Finally, the **Document plan** process step aims at verifying and auditing the plans. A summary of the performed planning work is documented in the project specification or in a project directive. The summary shall highlight the critical path, risks and assumptions. The documents are placed under configuration control.

### 3.4.2 Risk identification

The process for Manage Project Risks in projects is under the responsibility of the director of Programmes, Quality & Strategy. The process is illustrated in Figure 3-11.

**Figure 3-11 Manage Project Risks process**

Inputs to the Manage Project Risks process are the project schedule, customer requirements and the project directive. The output is a project schedule risk analysis model.
In the **Identify risks** process and process step each function is contributing supported by the Handbook for Project Risk Management and the Handbook for Management of Opportunities on Projects.

The following two processes aims at **Reviewing** and **Consolidating** risk in the risk management system.

The final step in the **Identify risks** process is the **Link Risks to Schedule in Toolset** process step resulting in a project schedule with linked risks. This process step is described in the Handbook to Schedule Risk Analysis but is not supported by a model adapted to the company’s tools and processes.

When the project schedule with linked risks is created the **Analyze/Evaluate** process starts by **Defining Mitigation Action Plans for Significant Risks**. This is performed by each risk owner aided by a risk identification template.

Next, the risk owner and Project Controller **Updates the Risk Register**.

This is followed by **Updating Project Critical Documents, Cost models, Schedule (plan), and Summary Schedule for Toolset**. These updates are performed by the project manager, technical project manager and the ILS manager. They are supported by templates and by Handbooks on Project Risk Management, Risk and Opportunity Management in Projects and Schedule Risk Analysis.

Finally, the project management team **Perform Schedule Risk Analysis at chosen confidences**. This process step is described in the Handbook to Schedule Risk Analysis but is not supported by a model adapted to the company’s tools and processes.

### 4 Case study

This section provides a description of the case study carried out during the research. The methodology of the case study starts with defining the company background and project background followed by gathering data. Next, an analysis of the data and the process is described. This is concluded as a developed theoretical model described in section 6.
4.1 **Company background**

The company is a matrix organization where the functional departments staff the projects. The company has two project management departments; one for delivery projects and one for support projects. These are supported by engineering management within the Engineering function. Responsibility for the risk management processes lies with the Finance function.

![Figure 4-1 Company organization](image)

Projects are organized according to Figure 4-2. In addition, sub-managers are appointed as applicable to the project size.

![Figure 4-2 Project organization](image)

4.2 **Project background**

The project started in January 2014 as part of a delivery project with the scope of integrating a purchased unit on company platform. The scope also includes production of an interface carrier to be mounted between the unit and the platform. The project team consisted of project manager, operations manager with staff, Test manager with...
staff and procurement manager. This type of projects is common within the company’s delivery projects and thus meets Yin’s (Yin, 2007) criteria for a single-case-study.

Figure 4-3 Simplified model of project scope

4.3 Scheduling and risk data collection

The initial schedule, held in MS Project©, contained six work packages with a total of 47 activities. 13 of these activities had successors and the remaining activities were scheduled with fixed start dates. Activity durations were estimated by the project manager. The project used the standard MS Project© calendar without modifications for holidays. Resources were allocated outside the MS Project© schedule in Primavera©.

At the time of the study the project had completed the initial activities but was halted due to delayed third-party deliveries. This required the project schedule (Figure 4-4) to be updated and provided the case study an opportunity to analyze the scheduling process.

The schedule updating was performed by the project manager during a one hour session with attendance of this paper’s author. Inputs to the schedule included the operations manager’s production schedule and revised supplier delivery dates. In the updating work, special attention was paid to meet the PMI recommendation that *the start of every activity has a logical relationship from a predecessor and the finish of every activity has a logical relationship to a successor* (Project Management Institute, 2011). The resulting schedule in Figure 4-5 provides logically linked work packages and/or activities. The work package “Platform Integration” with the activity “Rebuild of Platform” has no start constraint and is currently scheduled at the project start date which has passed. All prerequisites are in place for this activity to be started but it has no resources. When resources are assigned to the activity it will be scheduled and the duration estimate will
4 Case study

be updated.

At the time of updating the plan the activity “Assembly” (reference Pr1) was started and the remaining work was estimated to 15 days. Figure 4-6 shows the network of work packages which can be assigned to teams or individuals. It also highlights “System Verification” as the only work package on the critical path. The preceding work packages have four months free float to the critical path.

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6 The "Info" work package is also on a critical path but is disregarded as it only contains milestones of informative character.

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DATA GATHERING FOR SCHEDULE RISK ANALYSIS 25
The durations in the schedules were estimated by the Operations manager (Production of Carrier activities) and by the project manager (remaining activities). All estimates were single point estimates which were considered as optimistic values (Project manager, 2014).

5 Analysis and discussion

This section provides the author’s analysis of the literature and of the case study. The case study analysis is based on the documented observations and the literature research.

The literature research started with reviewing literature on the topic of scheduling. Findings from this review can be regarded as best practices but it shall be noted that the majority of available literature refers to PMI’s PMBOK (Project Management Institute, 2013). As a result the findings may be considered bias. However, since PMI has certified over 590 000 project management practitioners worldwide (Project Management Institute, u.d.) and that the studied company uses the PMI standards, the findings should be considered valid.

Findings from the next research topic, risk data collection, provide an overview of methods used in data gathering. The validity of the findings should be considered reliable with reference to the sources used in the research. However, the findings do not answer the research question “How do successful organizations gather data for schedule risk analysis?” They do provide an overview of data gathering methods but not any references to specific (successful) organizations – this is considered to be covered by the...
findings from the scheduling literature review. Any future research aimed at answering the question “How do successful organizations gather data for schedule risk analysis?” should include benchmarking of successful organizations’ methods for data gathering. This benchmark should go in depth of the organization to define the mechanisms for success by reviewing the organizational culture, communication patterns, documentation structures and leadership. This paper does not go into such detail as it is considered out of scope. Further, the limited access to resources for this research excludes such in-depth research.

The third research topic aims at answering the question “How can the company’s current processes be used or adapted to gather quality data for schedule risk analysis?” by reviewing the company’s processes. The reviewing of processes took an inductive case study approach. Data is derived from the company’s process management system and the data should be regarded reliable. The results are valid only for the studied company but they are not verified by the company’s process owners and must be regarded accordingly.

The case study of the project scheduling process aimed at gathering further information to provide an answer to the question “How can the company’s current processes be used or adapted to gather quality data for schedule risk analysis?” by observing the application of scheduling processes. The studied project was chosen under the assumption that it could be regarded as a “typical” company project. This assumption could not be challenged as the company did not sponsor this research paper. Result validity is limited to apply to the case study project. However, as the case study is considered to be typical the results could relate to any company project.

5.1 Literature research

Literature review reveals a process beginning with scope definition and creation of the WBS. This is followed by scheduling which should generate a network of sequenced activities. With the network established critical path evaluations should performed to root out any non-conformances to the project scope. A robust schedule should have defined dependencies, agreed resource assignments and reliable duration estimates.

The current company process structure indicates that planning is performed at two levels; Master schedule level and Detail schedule level. In the master schedule level the work packages’ activities are scheduled considering the project relevant calendars.
Activities are also identified in the Detail schedule level by the lower tiers in the project organization. Dividing the scheduling process into these two levels implies that each level of planning is iterated separately which can impose unnecessary scheduling constraints. Rather than having two levels of planning there should be one process for creating schedule to an “appropriate level”. This will provide for tailoring the level of detail to each project. Further, this will provide for an iterative planning process as schedules are detailed as the project progresses.

In both levels of scheduling activities (Create outline schedule and Detail planning) the process description states that “Unresolved scheduling conflicts can in exceptional cases be added to the risk list”. This indicates a reluctance to manage risks that are not considered “exceptional”. Such reluctance can be a risk in itself if risks are ignored.

Project risk identification and analysis/evaluation is under the responsibility of the Director of Programmes, Quality and Strategy and the outputs of these processes are schedule and schedule risk analysis models. However, as the case study shows, schedule risk analyses are not performed in the company’s projects. The consequence of this is that project risks are identified and reported but the responsibilities for analyzing and managing each risk is not defined.

The company’s current processes for schedule risk analysis are defined but not in use. One reason for this is that the planning responsibility is assigned to one line function; Project Support which in daily terms is called Project Planning - its previous name. The Project Support function is process owner for planning and scheduling and their associated toolsets. However, the function has no mandate to lead the planning work in projects. As a result the Project Support function is limited to support the projects’ managers in using the planning tools, not in the planning work. This, in combination with limited time for planning, undermines a planning culture. To remedy this, the process and toolset responsibility should lie with the Director of Programmes, Quality and Strategy who lead the project managers and the Project support function. This would emphasize that planning is essential for successful project execution. Further, this would delegate the planning work to the projects’ sub-managers who are best suited to provide realistic plans. In addition, this would also provide a logical flow from scope definition to scheduling and risk analysis.
5 Analysis and discussion

5.2 Case study

The case study’s initial schedule did not provide an accessible view of the project as it contained few linked work packages or activities. Further, the activity descriptions were ambiguous and incomplete which rendered a schedule that could not be easily understood by others than the scheduler – in this case the project manager. However, the case study shows that reliable schedules can be generated without much effort if industry best practices are used. Within the one-hour updating session a logical, constraint free network describing the work packages was created. This network can be easily understood by the stakeholders.

One work package was not in the initial schedule but was assumed to be performed within the project scope nevertheless. This work package and its activity were identified during the creation of the logical network and is a dangler in the updated schedule. The project manager was tempted to assign an estimated start date to the activity but wisely did not do so as he realized that this would have imposed constraints to the schedule. The dangler activity needs to be addressed before the plan can be base-lined. Nor the initial or the updated MS Project© schedules had any resources assigned since resource assignment is held in another planning tool, namely Primavera©. Since resource
assignments are imperative to the risk analysis, as they have great impact on durations, the planning should consider the resource assignments in Primavera©.

Some activities’ durations were considered optimistic. Using these in the schedule imposes risk to the project as they are less likely to be met. Further, as it is known that optimistic estimates are used the schedule cannot be relied upon. This can be avoided by using three-point estimates where the optimistic value is complemented by most likely and pessimistic values.

In summary, the company’s strategic goal of achieving a changed planning culture with increased delivery precision and thereby decreased costs and risks (Company, 2014) is highly relevant. The case study shows that the company’s planning processes are not used and that industry best practices are not considered.

6 Schedule Risk Analysis Model

The following proposed model for Schedule Risk Analysis is the output from the case study and from analyses of the company's processes. The model will answer the third and final research question; “How can the company’s current processes be used or adapted to gather quality data for schedule risk analysis?”

The target groups for the SRA model are project managers, project planners, project sub-system managers and the company’s Finance function.

6.1 Organization

This proposed model uses the current organizations for the company and its projects as outlined in Figure 6-1 and Figure 6-2.
6.2 Process
A completed schedule risk analysis is preceded by two processes; Scope management and Time management. The Director of Programmes, Quality and Strategy is responsible for the projects’ compliance to these two processes.

6.2.1 Scope management
Scope management is the process of defining all the work required to successfully complete the project. This process is managed by the project manager supported by the project management team. Process status is reported to the Director of Programmes, Quality & Strategy.

Stakeholder requirements provide input to the scope management process and are defined in the customer requirements, organizational requirements and by the company’s products.
Scope management includes three processes: Analysis of project requirements, Define structure for project scope and Allocate responsibility.

**Analysis of project requirements** includes defining what the project shall deliver in terms of:

- Customer deliveries – products, services, reports, etc.
- Organizational deliveries – financial results, reports, etc.
- Company’s products – current and desired technical maturity, etc.

The preferred technique for defining deliverables is using focus groups and the objective is to define the requirements attached to deliverables.

In the **Define structure for project scope** process the identified deliveries are documented as elements in a WBS and its associated WBS dictionary. Each WBS component must be 100% satisfied by its child elements. Level of effort components are to be separated from discrete components. The WBS is documented in Primavera©.

The project manager **allocates responsibility** for deliveries by assigning a responsible manager in Primavera© for each WBS element.

**Validate scope** involves inspection and group decision-making techniques to formally secure all stakeholders’ acceptance of the project deliverables. With secured acceptance the WBS is base-lined and placed under configuration control.

The output of the scope management process is a delivery-oriented WBS that defines the total scope of the project.

### 6.2.2 Time management

Time management is the process of managing the project’s execution in a timely manner. The time management process can be used on a high level project schedule or on integrated detailed schedules.

Each work package in the WBS is analyzed to **identify activities** required to satisfy its deliverables. The work packages are decomposed into activities to a relevant level that provides for efficient monitoring. Whenever possible, standard activities or activity lists from previous projects should be used and tailored as applicable. Expert judgment, provided by subject matter experts, should define the activities. In the early stages of planning when information is less defined, rolling wave planning can define the short
term activities in detail and the long-term activities less comprehensively. As the project progresses and additional information is available the activity planning is progressively detailed. Activities without a defined preceding activity are to be regarded as successors to the start milestone. As the project is initiated by the start milestone, these activities’ prerequisites are considered met. Activities without successors do not lead to the project’s goal and shall be removed.

Activities are sequenced by identifying dependencies. In Primavera© the activities are sequenced by defining their relationships in Finish to start (FS) dependencies. Lags should be defined as separate activities to facilitate for redefining their duration.

Estimates of resources required to complete the activities are documented in the WBS dictionary. In addition, personnel resources and cost estimates are added to the activities in Primavera© by resource categories. This provides a bottom-up estimate which aggregates to the work packages’ work and costs.

Estimate duration uses the activity’s requirements of resource type, resource quantity and stakeholder calendars to provide an outline schedule documented in Primavera©. The recommended technique for defining duration is by expert judgment. In addition, questionnaires and surveys can provide information from a large population and can be used to define duration for a common activity performed by different projects.

The duration estimates shall include a three-point estimate of the most likely, optimistic and pessimistic values for each activity.

- Most likely corresponds to “normal” or “as is” conditions. This is the estimated duration if standard resources are used under normal conditions.
- Optimistic values are the estimated duration if senior or expert resources are used, or if circumstances are ideal. These prerequisites provide an opportunity to shorten the duration but may increase costs.
- Pessimistic values are estimates of duration if the majority of things that can go wrong will wrong. These circumstances must be monitored but do not require external mitigation activities – they are mitigated by executing the project according to plan and addressing issues.
Optimistic and pessimistic values are supported by rationale statements describing the factors that generate the values. These statements provide input to the project risk register.

A probability distribution of the three-point estimates shall be documented in a text field in Primavera©. Most commercially available tools for schedule risk analysis with Monte Carlo method allow the use of numerous distributions. For practical reasons, such as easy reviewing, the following distributions should be used (Langhé, 2013):

Triangular - when the maximum, minimum and most likely values are known. This distribution is used as an alternative to the normal distribution mainly due to skewness.

![Triangular distribution](image)

**Figure 6-4 Triangular distributions**

PERT – the preferred distribution which provides a triangular distribution with rounded shape. It indicates that values closer to the most likely have a higher probability of occurring.
Uniform – this distribution can be used as a rough estimate or may be used if scarce or no data is available. It denotes that each value has an equal probability of occurring.
With the previous processes completed the **outline schedule** is created in Primavera. At this point it is important to evaluate the resource assignments versus the activity duration to determine if is feasible to staff the activity as required.

**Define project milestones** involves defining milestones for project maturity to be used in project monitoring. These are derived from the stakeholder’s requirements (LCM gates, customer reviews, financial reporting requirements, etc.) and added to the outline schedule.

**Perform schedule risk analysis** is the process of assessing the confidence in achieving project milestones by using Monte Carlo simulation techniques.

Commercially available software is used to run multiple simulations of the project schedule. Outputs from the simulations include:

- Histograms showing the probability distributions for achieving the project milestones
- Tornado graph showing the activities with highest risk associated to achieving milestones
- Correlations between data sets

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**Figure 6-7 Example of activity duration estimates based on case study activities**
This information is used for prioritizing risks, plan mitigation actions and for defining contingency reserves.

The following example of a Monte Carlo simulation uses data from the case study (section 4.3). This example simulation used an Excel template from Vertex42 (Vertex42, 2015).

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<td>System Test</td>
<td>18</td>
<td>20</td>
<td>22</td>
<td>PERT</td>
<td>20.0</td>
<td>*Most likely date corresponds to Supplier's Pessimistic date</td>
<td>Opportunity to decrease duration</td>
</tr>
<tr>
<td>I</td>
<td>System verification Unit (Supplier's verification)</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td>PERT</td>
<td>19.7</td>
<td>*Most likely date corresponds to Supplier's Pessimistic date</td>
<td>Opportunity to decrease duration</td>
</tr>
</tbody>
</table>

**Figure 6-8 Data from case study project used in Monte Carlo simulation**

Activity duration data and associated distributions provides input parameters to the simulation. A Monte Carlo simulation of 1000 samples provides the following information:

- Probabilistic durations for completing activities A and B (Figure 6-9)
- Probabilistic durations for completing activities E, H and I (Figure 6-10)
- Probabilistic durations for completing all five activities (Figure 6-11)
- Duration for completing activities with 20% and 80% confidence (Figure 6-12)
In a project with a fixed finish date the information provides the probability of finishing on time.
7 Conclusions

In a project with a stated risk level the information provides the probabilistic date for finishing.

6.3 Prerequisites

The implementation of this process requires some managerial inputs. These include

- Management commitment to foster a culture of planning for uncertainties
- Provide a software solution for Monte Carlo simulations that integrates with the company's systems for risk management, scheduling and configuration control
- Provide training in estimating techniques

7 Conclusions

This section will conclude if the research goal stated at the beginning of this paper were met. The research followed the methodology outlined in the beginning of this paper, namely by first reviewing existing literature on the topic of schedule risk analysis. Second, the company's processes were analyzed to define the operational context for schedule risk analysis. Third, a case study of an ongoing project provided an example of how the company processes are used in practice. These three areas were then analyzed and discussed on how the company applies the recommended best practices. Finally, a model process was outlined based on the analysis and discussion.

This section will start by assessing if the three questions raised are adequately addressed. Next, the adherence to the research goal is discussed and, finally, recommended future extensions of this research are listed.

7.1 Question 1: How do successful organizations schedule their project?

The question “How do successful organizations schedule their project?” was answered by exploring existing literature on the topics of scope management and scheduling. Findings are detailed in the Data and literature research section of this paper. The results validity is founded in the use of literature coherent with PMI’s standards. The results are summarized as follows.

Project management best practices states that the main input to building a robust schedule for schedule risk analysis is a well-defined WBS that describes the total project scope subdivided into smaller, more manageable parts. The WBS is surrounded by
common misconceptions and organizations could benefit from thoroughly train managers in scope management methodology and tools to avoid common pitfalls.

Scheduling, or Time management, best practices involves the creation of a constraint free, logically linked schedule with defined dependencies between activities. Each activity resource requirements should be defined prior to estimating durations. Duration estimates should use values for most likely, optimistic and pessimistic durations yielding three-point estimates. Further, the probability distribution for the estimates should be defined.

### 7.2 Question 2: How do successful organizations gather data for schedule risk analysis?

To answer the question “How do successful organizations gather data for schedule risk analysis?” the research focused on literature describing data collection methods recommended in the PMBOK (Project Management Institute, 2013). These results do not specifically define how successful organizations gather data. However, the question is answered implicitly in the defined best practices. These best practices state that scope definition, and its output WBS, is the main input to scheduling. Further, best practices state that the scheduling process should result in a constraint free, logically linked schedule with defined activity dependencies. The following summarizes the analysis results described in the Risk data collection techniques section:

Data gathering in the risk identification context involves eliciting information from expertise. The methods involves various communication techniques spanning from interviewing individuals, over group assessments techniques to surveys aimed at large populations. More passive information gathering such as documentation analysis and observations are also recommended.

### 7.3 Question 3: How can the company’s current processes be used or adapted to gather quality data for schedule risk analysis?

The third question “How can the company’s current processes be used or adapted to gather quality data for schedule risk analysis?” is covered in the Schedule Risk Analysis Model section. In the Schedule Risk Analysis Model section the findings from analyses of the company processes and the case study are used as input to define a company tailored process that adheres to industry best practices.
The tailoring involves emphasizing the scope management process and adapting the scheduling process to be suitable for all size projects or sub-projects. Further, the process for estimating inputs to schedule risk analysis is detailed.

The PMBOK (Project Management Institute, 2013) and other cited literature defines methods for estimating and calculating scheduling data in the process for schedule management. Further, in the PMBOK, risk management is a separate process. The proposed model combines these two processes by requiring duration estimates to be associated with rationale for the optimistic and pessimistic estimates. This provides incentive for risk identification and for considering mitigation activities earlier in the planning process. The case study clearly shows that the company is short of a structured planning and risk management culture. With little effort, great improvements can be gained by requiring the scheduler to actively consider risks in a structured manner.

Data from the case study, used in an example Monte Carlo simulation, provides data for deciding on level of acceptable risk.

7.4 General conclusions

This research shows that the company can improve its project performance by introducing a model for gathering data for schedule risk analysis. Introducing a new model may seem cumbersome at first, but it does not need to be. The three project management disciplines analyzed in this report (scope management, scheduling and risk management) are performed in the company's current and past projects. However, the methodology for how these disciplines are performed needs improvement. By implementing a rigid scope management the company can greatly improve project performance by avoiding scope creep and by providing the project team with a clear view of the project deliverables. This will be beneficiary to other project management disciplines such as communication management and human resource management.

Improvements to the company's scheduling process requires an improved knowledge of scheduling throughout the organization. The current scheduling process, performed by one line function, does not provide robust schedules suitable for quantitative schedule risk analyses. As a result, each company project is at risk of not meeting the project's objectives or of missing opportunities. To remedy this managers at all levels in the company, primarily in the project organizations, should be trained in scheduling methodology. The first step should be to require all schedules to adhere to the three
main quality attributes; no fixed or compulsory dates, all activities have predecessors and successors and defined dependencies (Frago, 2013). Again, this must not be a complicated or expensive implementation. An example of this is the case study where the schedule was greatly improved after only a one hour updating session. However, the model will only prove useful if it is endorsed by top management and adequately implemented. This includes introducing a company culture of project planning which is non-existing today. With a culture of project planning each project will have the necessary prerequisites for identifying schedule risks which will provide for identifying additional related risks including, but not limited to, technical, financial and resource risks. Further, this will provide for Earned Value Management (EVM) analyses as activity progress is reported.

The quality of each project’s planning of scope, schedule and risk management will directly affect the quality of the company budgets and, subsequently, the company’s financial results. This should be a strong argument for initiating improvements of the company’s planning culture without delay.

7.5 Research goal
The goal formulated for this research was “to outline a company-tailored model for gathering input data to schedule risk analyses.” This goal was covered by answering the three research questions.

This paper provides the necessary background data for implementing the proposed process model at the company.

8 Recommendations for future research

The proposed model is defined at sufficient detail to provide for implementation at the company. However, there are additional methods that can be implemented to further improve the risk analyses.

A method for range estimating could be detailed. Range estimating is a methodology to determine the probability of a cost overrun (or profit underrun) for any level of estimate and determine the required contingency needed in the estimate to achieve any desired level of confidence (AACE International, 2008).
A method for using parametric estimates in risk analysis and contingency determination could also be explored. AACE International provides a recommended practice defining a method used to estimate contingency based on risk parameters (e.g. level of scope definition, process complexity, etc.) (AACE International, 2009).

9 References


(2014, September 15). Project manager. (M. Mory, Interviewer)


