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THE INFLUENCE OF PROJECT RESOURCE ALLOCATION ON THE RESOURCE CAPACITY OF THE BUSINESS PROCESSES

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Abstract

In small and medium enterprises, resources from within the company are often used to fulfil small-scale projects. This paper discusses the influence of project resource allocation on the operational workflow of small and medium enterprises based on a case study. More precisely, the capacity of certain business operations will be lowered due to the allocation of scarce resources to projects. Subsequently, this might result in a temporarily lower throughput in the business processes and thus a potential loss of profitability. As a result, project scheduling and resource management have a clear impact on the planning and execution of the daily operations. In case that the deterministic estimates of project durations and costs are used, without accounting for risk and uncertainty, project delays are highly likely. Given the relation between project and business resource allocation, project delays might lead to difficulties in meeting targets in the daily operations. This paper presents an approach to incorporate the above effect in the decision-making process of portfolio management, i.e. the choice to initiate a project given the negative impact on the business processes. The decision-making process that results from this fundamental trade-off is demonstrated using a real-life project, which could provide valuable insights to project managers in small and medium enterprises.

1. Foreword

Before you read the remainder of this paper, it might be useful to clarify how this work has begun and how it finally resulted in – in my view – an exciting search for better control done by young students from our university. In my course module “Project Management” (PM) at the Faculty of Economics and Business Administration, I give my master students a full overview on how to manage a project using scheduling techniques, risk analysis methodologies and control methods such as Earned Value Management and its time-based extension Earned Schedule. Part of the evaluation of this course module is based on a written exam containing exercises and questions to test their understanding on the topic. However, another important part of the final evaluation consists of a group assignment in which I ask my students to rely on the PM concepts discussed in class and apply them in a real and critical way. Rather than giving my students a well-defined task to solve, I give them full freedom to explore the exiting world of PM, and ask them to apply and criticize concepts, improve them, tell me why some concepts work, and other fail, and any theme is good, as long as it is related to the course content. The best group assignments are nominated for the PMI Belgium University Contest and the winner is then invited to present their findings to professional project managers.

3. Project description

A commonly executed project between SME concerns the construction of an exhibition stand. We analysed the specific case of a small company that wishes to be present at a local fair in order to attract new customers. The company is specialized in the construction and installation of fireplaces and interior design. The exhibition stand will mimic a living room equipped with cabinets and fireplaces. In doing so, the company can exhibit their solutions to potential prospects. **Figure 1** shows a visualization of the exhibition stand that the company wishes to construct at a fair.

Figure 1: The project consists of building an exhibition stand as shown on the CAD drawing.

The project can be roughly divided into two phases: a preparation phase and a construction phase. The construction phase entails building the exhibition stand at the fair and is strictly limited to three days. In order to complete the construction within this tight time window, the company plans to complete a significant amount of work in advance during the

2. Introduction

This paper explores the effect of project execution on operational workflows which is the result of a group assignment in the course “Project Management” by Mario Vanhoucke (lecturer) and Tom Servranckx (assistant). Laura Vanacker and Olivier Van Raemdonck – two students Business Engineering at Ghent University – have accepted this challenge with pleasure and have translated the PM theory into practice and this paper is a summary of the work they have done. The objective of this paper is to investigate the influence of project execution on the business processes in small and medium enterprises (SME). This should be considered during project execution decisions as a part of project portfolio management in SME. The structure of this paper is as follows. Section 3 presents a general description of a real-life project and the business context. The construction of a baseline schedule and the analysis of the project schedule risks are concisely explained in section 4. Section 5 presents a thorough decision analysis of the project and examines the influence of resource allocation on business processes. Section 5 discusses the results of our analysis. Finally, some general conclusions are provided in section 6.

preparation phase. During this phase, employees can only be assigned to the project given a half-time work regime since they should commit sufficient time to the daily operations of the business. The complete project consists of 42 activities, executed by 11 resource types. Since all the required resources are available within the company, no subcontractors are involved in the project. **Figure 2** presents a timeline of the two phases.

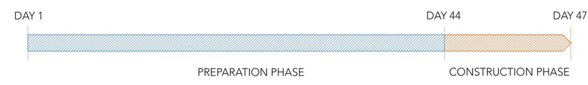


Figure 2: Timeline of the two project phases.

Given the distinct nature of both phases, the objective of both phases differs as well. On the one hand, the objective of the construction phase is to minimize the project makespan. This problem is known as the resource-constrained project scheduling problem (RCPSP) (Demeulemeester and Herroelen, 2002). In the course module, we have also discussed other objectives such as the resource-constrained project with discounted cash flows (RCPDC) (Herroelen et al., 1997), resource levelling projects (RLP) (Brinkmann and Neumann, 1996), resource-constrained project with work continuity (RCPWC) (Vanhoucke, 2006) and Resource availability cost problem (RACP) (Möhring, 1984). On the other hand, the objective in the preparation phase is to minimize costs.

4. Dynamic scheduling of the project

In section 4.1, the baseline schedule of the exhibition project is constructed to use as a point-of-reference throughout the solution procedure. Section 4.2 discusses an additional risk analysis that supports the cost-benefit analysis. An overview of the solution approach is provided in **table 1**.

4.1. Baseline scheduling

The first step in the construction of the baseline schedule is to break down the project into work packages and activities. Based on the Work Breakdown Structure (WBS), an activity on the node (AON) network diagram was constructed in order to model the project network logic (see **figure 3**). The activity properties are displayed in **tables 2 and 3**. For each activity, an optimistic (a), realistic (m) and pessimistic (b) duration estimates is provided as well as the resource requirements. In **table 2**, the activity durations of activities 1 to 26 (i.e. preparation phase) are expressed in days, while the activity durations of activities 27 to 42 (i.e. construction phase) in **table 3** are expressed in hours. The realistic (m) durations are used to construct the baseline schedule, while the optimistic (a) and pessimistic (b) estimates are only used during risk analysis. Since scarce resources are required to execute all project activities, the baseline schedule is constructed under the restriction of limited resources. The aim of the scheduling approach is to reach both scheduling objectives (i.e. cost minimization for the preparation phase and makespan minimization for the construction phase) in the baseline schedule. The result is a makespan of 48 days for the first phase; the second phase is completed in the fixed three-day time window. Consequently, the total project makespan is equal to 51 days. The baseline schedule acts as a point of reference for the simulation study that is discussed in the next section.

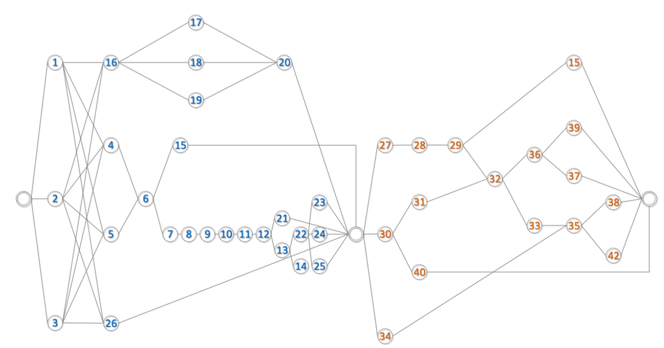


Figure 3: Network diagram of the project.

	Input	Results	Relevance	Sources of information
Baseline scheduling	Work breakdown structure Network diagram Resource constraints	Baseline schedule	Overview of project scale and duration	Interviews Survey
Risk analysis	PERT estimations Baseline schedule	Monte Carlo output	More realistic project estimates Improve project planning in relation to daily activities	Interviews Assumptions
Cost analysis	Baseline schedule Monte Carlo output	Total project cost estimation	Clear picture of all project costs	Interviews Financial statement Calculations
Bottleneck analysis	Baseline schedule Workflow of company Monte Carlo output	Estimated missed opportunity costs	Highlight consequences of using bottleneck resources in project	Interviews Process observation Calculations
Profitability analysis	Total project cost estimation Estimated missed opportunity costs Total project benefit estimation	Internal rate of return	Support project selection and portfolio management	Calculations

Table 1: Overview of solution approach.

ID	Task name	Task duration (days)			Resource requirements
		a	m	b	
1	Search for manufacturer	0,7	1,4	2,1	Manager (10%)
2	Search for two cabinet-makers firms	0,7	1,4	2,1	Manager (10%)
3	Meeting: Task division	1	1	1	Manager
4	Set up co-operation agreements	1	1	1	Manager
5	Reservation exhibition stand	1	3	7	Manager
6	Meeting: Zone division	1	1	1	Manager
7	First draft in CAD	1	2	3	CAD designer
8	Meeting: Draft discussion 1	1	1	1	CAD designer, manager
9	Second draft in CAD	1	2	3	CAD designer
10	Meeting: Draft discussion 2	1	1	1	CAD designer, manager
11	Third draft in CAD	1	1	2	CAD designer
12	Combine drafts to a final concept	1	1	1	CAD designer, manager
13	Conversion of CAD to CAM	2	3	4	Production manager (50%), CAD designer
14	Ordering and delivery of required materials	7	14	21	Production manager (50%)
15	Ordering and delivery of required fireplaces	7	14	21	Manager
16	Meeting: Marketing discussion 1	1	1	1	Marketing designer (50%), manager (50%)
17	Flyer design	1	2	3	Marketing designer (50%)
18	Voucher design	0,5	0,5	1	Marketing designer (50%)
19	Webpage design	0,5	0,5	1	Marketing designer (50%)
20	Meeting: Marketing discussion 2	1	1	1	Marketing designer (50%), manager (50%)
21	Search for subcontractors	1	1	1	Manager
22	Set up production schedule	1	2	2	Production manager (50%)
23	Production in wood workshop	5	6	7	Wood workshop worker (50%)
24	Production in stone workshop	2	3	3	Stone workshop worker
25	Production in metal workshop	2	2	3	Metal workshop worker
26	Construction exhibition stand (details in table 3)	3	3	3	-
27	Set up exhibition staff schedule	0,5	0,5	0,5	Manager

Table 2: Activity properties of preparation phase.

ID	Task name	Task duration (days)			Resource requirements
		a	m	b	
27	Instalment of gas lines and gas bottles	4	5	6	Plumber
28	Instalment of floor covering	4	5	6	Installer (700%)
29	Connect gas fires to gas lines	1	2	3	Installer (200%)
30	Instalment of flue system	4	5	6	Plumber
31	Connect gas fires to flue system	1	2	3	Plumber
32	Instalment of fireplace surroundings	84	96	108	Installer (1400%)
33	Instalment of ceiling	4	5	6	Installer (400%)
34	Preparatory electrical work	4	4	5	Electrician
35	Electrical work	2	3	4	Electrician
36	Painting and wall covering	10	12	14	Painter (200%)
37	Decoration	1,5	2	2,5	Painter
38	Instalment of TV's	1,5	2	2,5	Electrician
39	Paste stickers	2	2	2	Painter
40	Instalment flue extraction pump	1	2	3	Installer (200%)
41	Gas inspection	0,5	0,5	0,5	Plumber
42	Electrical inspection	0,5	0,5	0,5	Electrician

Table 3: Activity properties of construction phase.

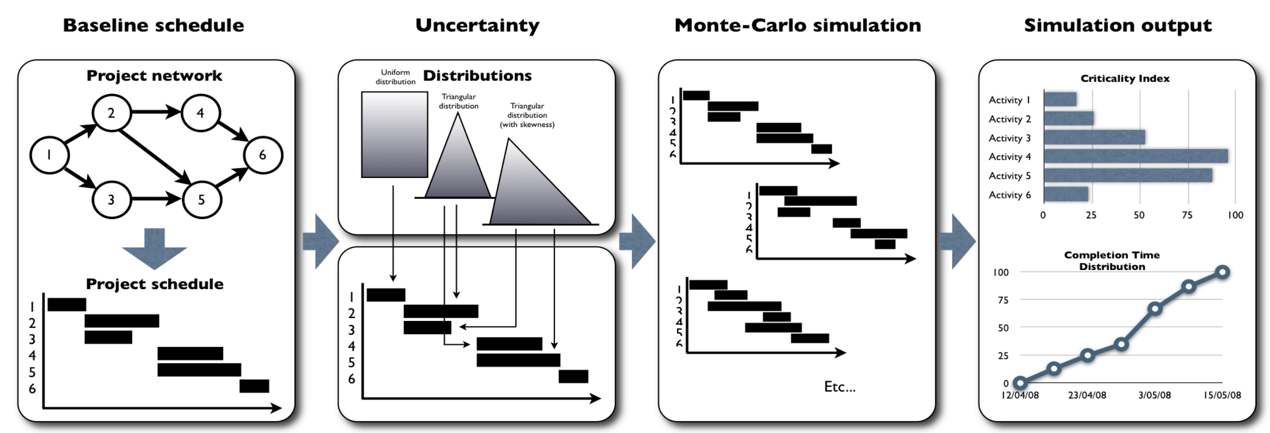
4.2. Risk analysis

The baseline schedule acts as a point-of-reference and assumes deterministic values for activity duration, cost and resource requirement. During project progress, however, the project manager is confronted with activity duration variability and thus the actual project execution will deviate from the baseline schedule. Therefore, risk analysis should be performed on top of the baseline schedule in order to make more reliable estimations of project duration and cost. **Figure 4** displays the four-step procedure of schedule risk analysis that was used for this case. The **first step**, called 'Baseline schedule' is already discussed in section 2.

Subsequently, the **second step** involves defining uncertainty for the project activities. Every project activity was given an optimistic (a), realistic (m) and pessimistic (b) duration estimate, resulting in triangular distribution for the activity durations. In **tables 2 and 3**, these three estimates are given for each activity. In **third step**, values are drawn from the triangular distributions in order to simulate a potential execution of the project. As a result, each execution run results in a project execution with a different project makespan and cost. After a sufficiently high number of simulation runs, the simulated project makespan and cost result in a histogram for the project makespan and cost in the **fourth step**. More simulation runs will result in a higher reliability of the estimated mean for the project makespan and cost. In this paper, 15,000 simulation runs are conducted as a higher number of simulation runs did not result in a significant improvement of the estimated mean of the project makespan and cost.

After the execution of 15,000 simulation runs using the triangular distribution, a histogram that shows the probability distribution for both the project makespan and cost was created, as shown in **figures 5 and 6**. Based on the risk analysis, it is shown that there is only a 12% probability that the preparation phase will be finished within the window of 48 weeks as determined in the baseline schedule. In case that the preparation phase would be initiated five days earlier, the probability to finish the project would increase to an acceptable 85%. Also, the following conclusions on the project cost could be determined. In 80% of the simulated runs, the total labour cost was €25,712 or less, while the maximum labour cost is equal to €27,399. The risk analysis thus provided the project manager with additional information on the total labour cost in the project and the expected total duration of the commitment to the project.

Figure 4: The four-step procedure of schedule risk analysis (Vanhoucke, 2012).



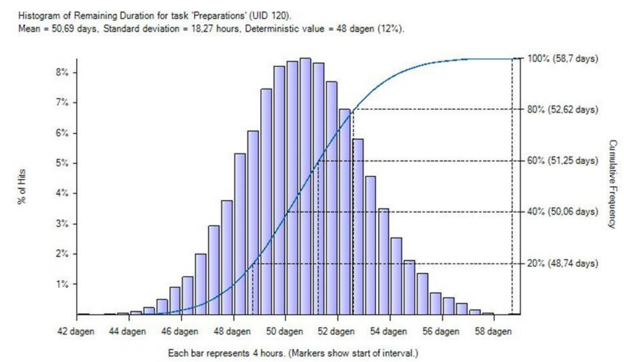


Figure 5: Histogram of possible durations.

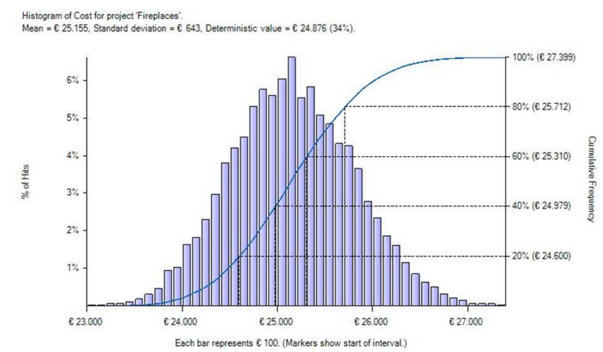


Figure 6: Histogram of possible labour costs.

5. Decision analysis

Since resources that are assigned to a project are temporarily unavailable in the daily operations of the company, the execution of the project has a negative impact on the company's throughput. This negative impact should be quantified to incorporate in the above financial analysis. Therefore, the missed opportunity cost of project execution should be added on top of the estimated labour costs resulting from the Monte Carlo simulations. Missed opportunity costs are defined as the benefits that were given up when a decision is made. Paragraph 5.1 elaborates on the impact of allocated project resources on the daily activities of the company, which results in these so-called missed opportunity costs. Based on the baseline schedule and cost-risk analysis discussed in the section, a cost comparison with the expected cash inflows is made to support the decision whether or not to execute the project. Paragraph 5.2 discusses the cost-benefit analysis and proposes a simple yet intuitive performance measure to assess the return on investment of the project.

5.1. Missed opportunity costs

As mentioned in section 2, the daily activities of the company consist of installing fireplaces. An abstraction of the operational workflow and capacities of the company are schematically shown in **figure 7**. The daily business of the company to manufacture fireplace consists of four sequential stages: the design stage, the assembly stage, the installation stage and the after sales. Each stage requires specialised resources within the company, respectively, designers, assemblers, installers and clerks. The daily business of the company should be clearly distinguished from the project that focuses on the installation and exploitation of an exhibition stand. The project requires the temporary use of one designer, two assemblers and two installers. Taking this simplified workflow into consideration when judging the project's return on investment is an important step towards a correct assessment. After all, the project is not a stand-alone operation and must be analysed in conjunction with the company's daily activities.

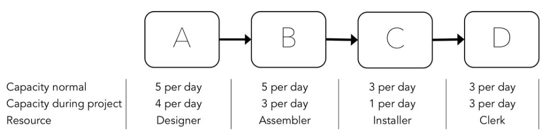


Figure 7: Simplified process workflow of the company's daily activities.

Customers enter the workflow, go through all four operations (A, B, C and D) in a pre-defined sequence and leave the system. A customer leaves the system after paying their invoice, which implies that the throughput of the system determines the earnings of the company. The more customers flow through the process workflow, the more earnings and thus profit the company will generate. The normal capacity rate, which is the maximum output rate under normal circumstances, is given for each operation. In this paper, we refer to a situation in which resources are not allocated to projects as 'normal circumstances'.

For example, only five customers can be processed by operation A on a daily basis. The required scarce resources for each operation are also given in **figure 7**. Given these limited capacities in the business workflow, the presented process also contains a bottleneck. A bottleneck is the operation in the workflow with the most restrictive capacity. Consequently, it determines the throughput of the entire process. In this process, operation C is the bottleneck as the available number of installers in the company can only process three customers per day. The other operations in the workflow have a higher throughput and thus the throughput of the entire workflow is constrained to three customers per day due to the limited capacity of operation C.

During the execution of the exhibition stand project, scarce resources will be drawn from the company because these resources are temporarily needed for the execution of project activities. This results in temporarily lower capacities for the daily operations. In **figure 7**, the 'Capacity normal' for each operation drops to the 'Capacity during project' during project execution. For example, the designers cannot work on operation A in the process workflow of the company while they should execute certain project activities. This reduces the throughput of operation A from five to four customers per day. In case that this would be the only operation affected by the execution of the project, this would not affect the throughput of the entire workflow since operation A is not the bottleneck in the workflow. However, the execution the project does affect other operations, including the bottleneck operation C. Therefore, the throughput of the entire workflow is reduced as the capacity of operation C is limited to one, rather than three, customer(s) per day. In summary, the total throughput of the system drops to one customer per day during project execution due to the allocation of bottleneck resources to the project.

As indicated before, the flow through the four operations in **figure 7** determines the earnings of the company. Any changes in the throughput of the process workflow will thus affect the earnings of the company. Consequently, these changes in customer throughput during project execution result in missed opportunity costs. These costs must be taken into account when assessing the profitability of the project, which will be discussed in the next section. Besides a lower throughput, a disproportionate change in the operation capacities will likely affect customer queues between two operations. It might happen that customers have to wait longer to get served at an operation because it cannot handle the inflow of customers due to a decreased capacity during project execution. This increase in waiting time and queue length might result in customer dissatisfaction, which puts long-term pressure on the profitability of the company. These effects should also be taken into account during decision-making in project portfolio management.

The goal of the exhibition project is to attract new customers in the process chain. However, earnings are not generated by customer inflow, but rather by customer outflow. The project will increase customer inflow, while it temporarily decreases customer outflow. This will result in missed opportunity costs and increased work in progress in the process chain.

For the sake of simplicity, the process workflow in **figure 7** presents an abstraction of reality. However, the above reasoning can be straightforwardly applied to more complex workflows. The actual process flow of the company consists of a larger number of operations and has an increased complexity as more resources are involved and minor capacity fluctuations occur unpredictably. Although an explanation of the complete business process is out of the scope of this paper, **table 4** provides a more detailed overview of the resources that are required in the daily operations of the company as well as the resources that are required in the project. Similar to the simplification presented in **figure 7**, the installers are the bottleneck resource in the workflow.

	Availability in company [units]	Amount used by project [hours]
CAD designer	2	80
Marketing designer	2	32
Manager	2	110
Production manager	1	44
Wood workshop worker	3	48
Metal workshop worker	2	16
Stone workshop worker	2	24
Painter	2	16
Installer	**14**	**110**
Plumber	2	12
Electrician	1	15
Salesperson	3	0
Clerk	1	0
Warehouse operator	1	0

Table 4: List of resources available to the company and the amount (h) used to carry out the project.

In case that the complex business workflow with resource constraints and capacities would be considered, the calculations of the opportunity costs would become too time-consuming for most SME. Therefore, a certain degree of simplification of the workflow, resources and capacities could result in a more understandable yet still reliable estimation of the opportunity costs. Given the workflow presented in **figure 7**, the throughput in the business process is limited by the bottleneck resource 'installer'. As a result, the customer throughput is limited to one customer per day, rather than three customers per day, due to the project commitment. Since the throughput of the production process determines the earnings of the company, we can estimate the loss of earnings related to the presence at the annual fair. Given the above rational, the opportunity costs are estimated to be €9,000 in the discussed case.

5.2. Profitability of project

The total cost of the project presented in this paper consists of material costs, risk-weighted labour costs, exploitation costs, deconstruction costs and missed opportunity costs. Taking all these costs into consideration, the total expected project cost is estimated to be around €65,332. However, the company has three other business partners involved in this project who are willing to contribute financially and cover a fair share of the estimated total project costs. Therefore, the total financial contribution of the considered company is fixed to €37,800, which is roughly 58% of the total project cost of €65,332. A slightly more detailed cost breakdown is provided in **table 5**.

	Estimated total cost	Estimated share of cost
Exploitation costs	€ 8,620	€ 2,155
Material costs	€ 21,000	€ 4,725
Labour costs *(at 80% probability)*	€ 25,712	€ 20,920
Opportunity costs	€ 9,000	€ 9,000
Deconstruction costs	€ 1,000	€ 1,000
Total	**€ 65,332**	**€ 37,800**

Table 5: Total project cost expressed by five different cost components.

This estimated project cost of €37,800 must be compared with the short-term revenues in order to assess the potential profitability of the project. A method that could be used to support this decision is the internal rate of return (IRR). According to this method, the expected cash inflows are discounted with a certain rate, the so-called internal rate of return, in such a way that the net present value of the total cash inflows equals the net present value of total cash outflows. The project generates a sufficient return in case that the IRR is higher than a minimum required rate of return. In **table 6**, we apply the IRR method to the project.

Month (n)	Estimated cash flow (C_n)	Formula IRR
0	-€37,800	$0 = \sum_{n=0}^{5} \frac{C_n}{(1 + IRR)^n}$
1	€12,500	
2	€16,666.66	**IRR = 10.91%**
3	€17,708.33	

Table 6: Expected cash flows and calculation of IRR.

In this project, the minimum rate of return is assumed equal to the profit margin on the daily operations, which amounts to approximately 10%. Therefore, the project should have at least an IRR of 10%. In order to estimate the short-term revenues that will be generated by the project, the company uses historic information on the expected number of visitors per stand at the annual fair. Under normal circumstances, the fair attracts 75,000 daily visitors who visit on average 10 stands per visitors out of the total number of 480 stands. Consequently, the company expects to attract 1562.5 visitors per day of which 10% might be potential prospects. Given historic data obtained within the company, they know that 20% of prospects place a purchase offer at the company for an average value of €1,500. This results in an expected daily profit generated by the exhibition stand equal to €5,208.33. Since the fair lasts 9 days, the excepted future profit generate at the fair is equal to €46,875. However, this future profit will not result in positive cash flows instantaneous as prospects will validate their purchase offer over different time horizons. From prior experience, the company knows that purchases are validated over three months after the finish of the fair according to the following distribution key: €12,500 in the first month, €16,666.66 in the second month and €17,708.33 in the third month. This information is summarized in **table 6**. As a result, the IRR amounts to 10.91%, which is slightly higher than the minimum required rate of 10%. Consequently, the IRR indicates that the project should be executed as the estimated short-term revenues generated in the project outweigh the estimated short-term costs related to the project. However, the profitability of the project can also be expressed using different metrics. For example, the number of customers that should be attracted at the exhibition stand in order to cover the costs related to the project, including the missed opportunity costs.

6. Discussion

The goal of the solution approach, as presented in **table 1**, is to support project selection decisions in project portfolio management for SME. The first step is to constructing a baseline schedule in order to have insight in the duration and development of the project. The baseline schedule serves as a point of reference throughout the entire cost-benefit analysis and has a central role in risk analysis. In this paper, risk analysis was performed using Monte Carlo simulations. The result of the risk analysis is a fairly reliable estimation of the project makespan as well as the costs related to the execution of the project. In order to make a well-considered decision on the execution of the exhibition stand project, all costs and expected revenues should be considered. This includes the missed opportunity costs that quantify the influence of project resource allocation on the business processes. In order to estimate the missed opportunity costs, the bottlenecks in the operational workflow of the company should be computed. This is not straightforward as bottleneck detection can be difficult in complex workflows. Moreover, bottleneck resources in a system are rarely fixed as they shift between operations when changes in the process occur. Since the detection of bottleneck resources is out of the scope of this paper, we refer to other literature (Li et al., 2009).

In this research, the execution of the project resulted in a capacity reduction of the bottleneck. However, other outcomes are also possible. It could be that a project does not demand bottleneck resources, such that the total capacity of the process is not affected by project resource allocation. Another possibility is that the bottleneck operation under normal conditions becomes a non-bottleneck operation during project execution and another operation becomes the bottleneck resource, which shifts the operational focus of the project manager accordingly. The missed opportunity costs are estimated based on the capacity reduction of the bottleneck and thus the reduction in throughput of the business workflow.

It should be mentioned that it is of crucial importance to the above analysis that realistic project duration estimates are used and that activity variability is taken into consideration during the assessment of the missed opportunity costs. First of all, the missed opportunity costs are proportional to the time during which the capacity of the operational workflow of the company is reduced. Therefore, an underestimation of the activity duration estimates results in an underestimation of the missed opportunity costs. As a result, it can lead to the decision to execute a project that does not contribute to the profitability of the company. Secondly, the schedule of the business operations is constructed based on the estimated project makespan. An underestimation of the project makespan will lead to delays in the daily operations, which might have a negative impact on queuing times and thus customer satisfaction. Consistently, an overestimation of activity durations could result in similar negative effects.

At last, all cost and benefits should be combined in a single metric: the internal rate of return. The IRR is a comprehensive measure for the evaluation of the profitability of the project. However, the company should not solely focus on this metric, but rather take the complete analysis into account. For example, the influence of project execution on the customer satisfaction and/or brand image is not included in the IRR as these effects are difficult to quantify.

7. Conclusion

A well-considered decision whether or not to execute a project should consist of a comprehensive analysis as presented above. Despite their importance, missed opportunity costs and effects on customer queuing times are regularly overlooked in the decision-making process. Especially in small and medium enterprises (SME), projects are considered stand-alone operations and the project execution decision is often reduced to a rough estimation of costs and benefits without taking risk or opportunity costs into account. However, SME are usually vulnerable to changes in the resource capacities of the process workflow. Therefore, the effects of project execution decisions on the daily operations of the business, and thus the earnings of the company, should definitely be analysed. The core of this paper is to provide an effective tool to support project selection decisions in portfolio management at SME.

> "At last, all cost and benefits should be combined in a single metric: the internal rate of return. The IRR is a comprehensive measure for the evaluation of the profitability of the project."

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