Software Project Management
(A.Y. 2018/2019) – Exam Solution

February 27^{th}, 2019

Preamble

The Silly Software company has been asked to develop a complex software system. You, as an employee of the company, have been appointed as Project Manager. The management is now asking you to provide some forecasting in order to decide on how to proceed with the project.

In deriving your prediction you should consider that the **week** gross salary of the emplyees is as following specified:

- *Senior developer:/Analysts* 2000€
- *Junior developer:* 1500€

Moreover historical data show that the company generally experiments a 50% overhead

Exercise 1.

At first in order to derive a more reliable estimation you sketch a set of workpackages (WPs) and tasks that you consider necessary in order to complete the project. Tasks expected durations and their mutual dependencies are detailed in Table 1.

Activity	**Activity Duration (weeks)**				
(Precedents)	**Optimistic (a)**	**Most likely (m)**	**Pessimistic (b)**	**Expected te**	**Standard deviation (s)**
T1.1	4	6	8	6	0,66
T1.2 (T1.1,T2.1)	2	7	12	7	1,66
T1.3 (T1.1,T3.1)	9	12	15	12	1
T2.1	8	12	16	12	1,33
T2.2 (T1.1,T2.1,T3.1)	3	6	9	6	1
T2.3 (T2.2,T1.3)	6	12	18	12	2
T3.1	4	6	14	7	1,66
T3.2 (T1.1,T3.1)	8	12	16	12	1,33
T3.3 (T1.2,T3.2)	10	14	18	14	1,33
T3.4 (T3.3)	11	12	19	13	1,33
T4.1 (T1.3.,T2.3)	5	9	13	9	1,33
T4.2 (T3.3,T4.1)	2	3	4	3	0,33

Table 1: Activities time estimates (in weeks)

To derive a first estimation for the project you apply the PERT approach. Therefore you compute:

- The duration of the project
- The probability of successfully terminating task T4.2 by week 46, task T2.2 by week 19 and task T3.4 by week 42.
- Compute the deadline by which the probability of having finished the project is 95%
- Immagine of being at week 19 into the project, and that all the tasks foreseen so far ended in time, with the exception of activity T2.2 that is currently delayed. Assuming that now the expected time by which this task will terminate is week 22 with a value for $\sigma = 1,33$. Provide both the probability of ending the project by week 46, and the week by which the probability of terminating the project is now equal to 95% (considering that no change occurred in relation to the duration and related probabilities of the still missing tasks).

Note: In deriving the PERT network you should try to reduce the number of nodes as much as possible **12 points**

Solution:

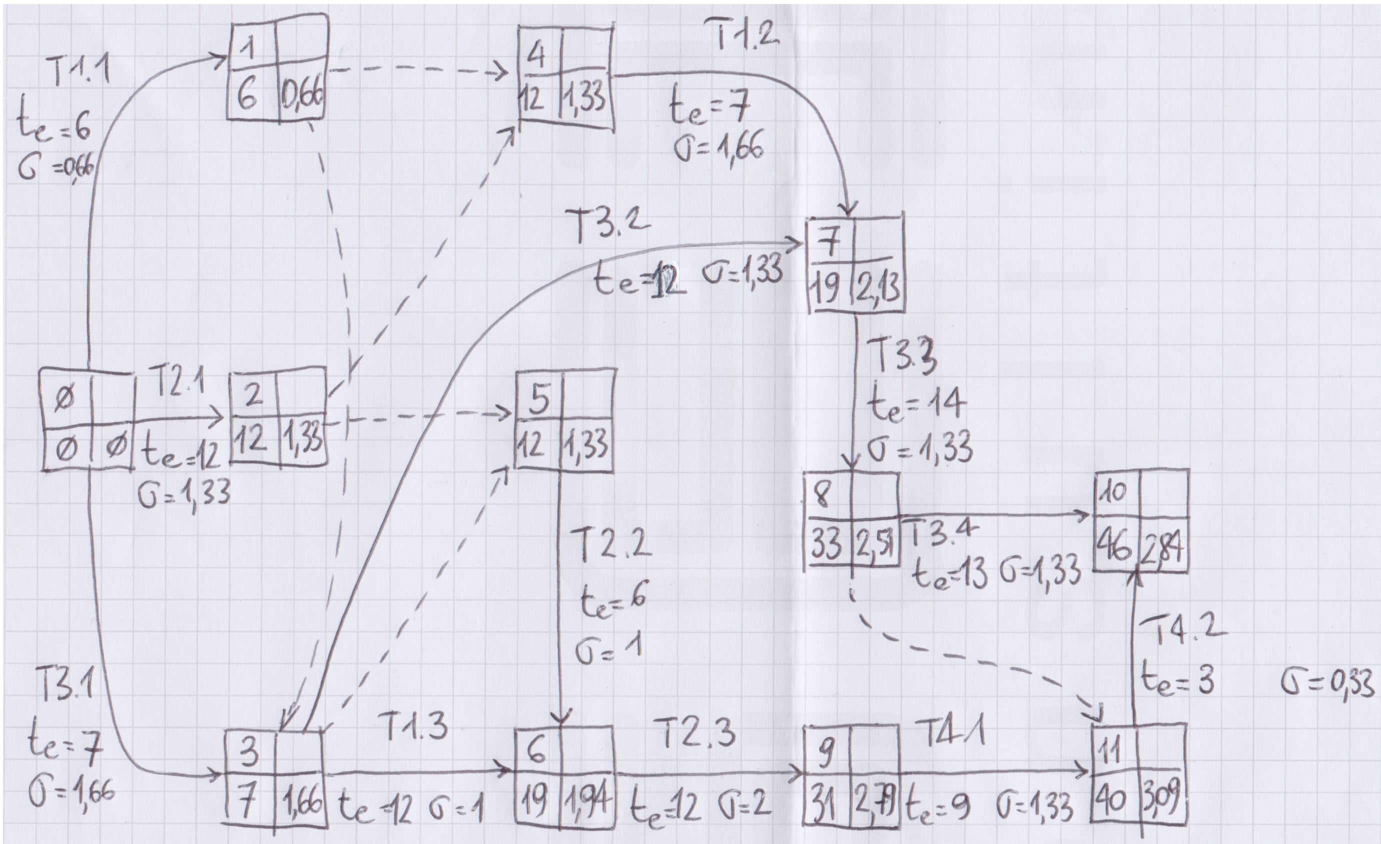

Figure 1: PERT Network

Accoding to the PERT network reported in Figure 1 we can conclude that:

- The expected duration of the project is 46 weeks
- The probability of terminating the various tasks by the given weeks is computed using the formula $Z = (T - t_e)/\sigma$ and then using the graph for Z to get the probability. As a result we get:
  - T4.2 by week 46: $0.965 = (46 - 43)/3.11$ corresponding to a probability of ≈0.82
  - T2.2 by week 19: $0.6 = (19 - 18)/1.66$ corresponding to a probability of ≈0.73
  - T3.4 by week 42: $1,41 = (42 - 46)/2.84$ corresponding to a probability of ≈0.08
- To compute the week by which the probability of having finished the project is 0.95 we can use the formula $T = Z * \sigma + t_e$ where for the value of Z we use the value 1.75. As a result we get ≈51 weeks
- To answer the question we could consider the need of running a new project in which the only tasks to perform are the ones still not started at week 19 (i.e. T3.3, T3.4, T2.3, T4.1, T4.2) in addition we have to consider task T2.2 for which we consider a duration of 3 weeks with a value for sigma equal to 33. We can then revise the value on the PERT network already derived in paticular recomputing the values for the path T2.2→T2.3→T4.1→T4.2 that will now end at week 46. Consequentely the probability of terminating the project by week 46 is still 0.5, and the time by which the probability of terminating the project is 95% is still ≈51 since the path terminating with T4.2 has now a value for sigma equal to ≈2,77.

Exercise 2.

Now you want to derive a plan applying the critical chain method. For each activity the duration you consider is the one reported in Table 1, and indicated as t_e, while as comfort zones you consider the ones corresponding to a duration leading to 95% of probability of terminating the activity itself. In addition you judge that 30% is the percentage to use to compute the project buffer and 20% the percentage for the feeding buffers (use ceiling to the whole week in order to approximate the numbers you get).

After having derived the sheduling for the project, according to the critical chain method, you want to derive a cost estimation allocating the resources indicated in Table 2 applying a uniform distribution over the duration of the activity. In deriving the plan you should consider that the following constraints could affect the total cost of the project:

- the company does not have more than 7 Senior Developers and 5 Junior Developers. The cost for recruitment activities accounts to 15000€ for each resource to be recruited.
- in order to simplify management activities, resources are charged to the project budget for a minimum of 2 weeks (i.e. in case a resource is assigned to a project and then released for less then 2 weeks in any case the budget to be considered is the one corresponding to two weeks)
- in order to simplify management activities, resources should not be released for less than two weeks, otherwise the costs that will be charged on the project will be in any case two weeks (i.e. in case a resource is assigned to the project then released and then again reallocated to the project with a resulting gap smaller than two weeks the cost to consider is in any case two weeks).

Task	**Effort**
T1.1	12 SD/0 JD
T1.2	7 SD/**57**[1]JD
T1.3	12 SD/24 JD
T2.1	24 SD/24 JD
T2.2	12 SD/6 JD
T2.3	12 SD/24 JD
T3.1	21 SD/21 JD
T3.2	24 SD/12 JD
T3.3	70 SD/42 JD
T3.4	52 SD/39 JD
T4.1	9 SD/18 JD
T4.2	3 SD/6 JD

Table 2: Foreseen effort for each project task in terms of Senior Developers (SD) and Junior Developers (JD)

1. Provide the resource allocation and compute the total cost, when no optimization is introduced to reduce the possible additional costs listed above.
2. Optimize as much as you can the plan, so to reduce the total project cost (consider that it is not possible to split the foreseen tasks in subtasks).

12 points

Solution:

From Figure 2 we can desume the following information:

- There are two different critical paths both of them leading to a Project buffer equal to 4 weeks
- There are two feeding buffers to consider:
  - (1) It is the one associted to path T1.1 and it results in one week
  - (2) It is associated to the paths ending with the activity T4.2. The maximal sum for the comfort zones is equal to 10 (path T1.3→T2.3→T4.1→T4.2)

To compute the cost of the project we have to consider the allocation of resources as reported in Figure 3. In the figure red is used after T1.1 and T4.3 to represent the two feeding buffers, while blue isused to represent the project buffers. In light red squares represent the fact that the activity has been anticipated in order to respect dependencies as consequence of the introduced feeding buffers. Finally light grey is used to represent the area in which it could be possible to move an activity.

[1]this was a typo ☹!! It was meant to be 7. In any case the correction will consider both possibilities as correct, even though it is not possible to have a uniform distribution over the weeks using an integer if 57 is used.

Activity (Precedents)	Activity Duration (weeks) Optimistic (a)	Most likely (m)	Pessimistic (b)	Expected te	Standard deviation (s)	End 95%	Comfort zones
T1.1	4	6	8	6	0,66	8	2
T1.2 (T1.1,T2.1)	2	7	12	7	1,66	10	3
T1.3 (T1.1,T3.1)	9	12	15	12	1	14	2
T2.1	8	12	16	12	1,33	15	3
T2.2 (T1.1,T2.1,T3.1)	3	6	9	6	1	8	2
T2.3 (T2.2,T1.3)	6	12	18	12	2	16	4
T3.1	4	6	14	7	1,66	10	3
T3.2 (T1.1,T3.1)	8	12	16	12	1,33	15	3
T3.3 (T1.2,T3.2)	10	14	18	14	1,33	17	3
T3.4 (T3.3)	11	12	19	13	1,33	16	3
T4.1 (T1.3.,T2.3)	5	9	13	9	1,33	12	3
T4.2 (T3.3,T4.1)	2	3	4	3	0,33	4	1

Table 3: Activities time estimates and corresponding comfort zones (considering 95% probability)

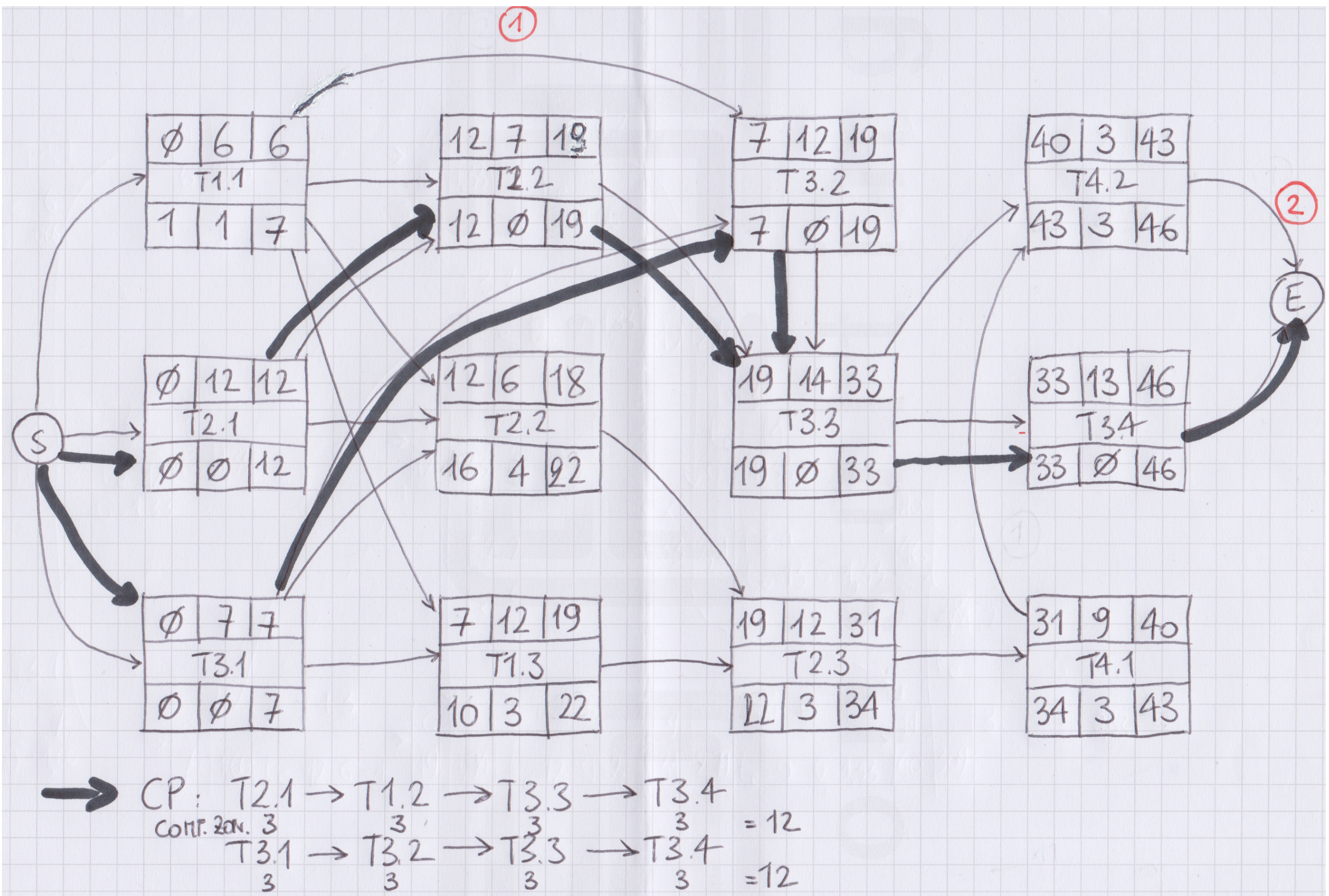

Figure 2: CPM network and buffers

Solution when and effort of 7 is considered for JD in relation to T1.2

1. In case no optimization is performed the total cost has to include the following factors:

   a At week 7 a SD is released and reaquired at week 8 and similarly it is done for 2 JD. According to the second constraint the PM will have to consider an additional week in relation to the total effort of senior developers and 2 additional weeks for junior developers

Weeks		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Tasks																										
T1.1	SD	2	2	2	2	2	2																			
	JD	0	0	0	0	0	0																			
T1.2	SD													1	1	1	1	1	1	1						
	JD													1	1	1	1	1	1	1						
T1.3	SD									1	1	1	1	1	1	1	1	1	1	1	1					
	JD									2	2	2	2	2	2	2	2	2	2	2	2					
T2.1	SD	2	2	2	2	2	2	2	2	2	2	2	2													
	JD	2	2	2	2	2	2	2	2	2	2	2	2													
T2.2	SD															2	2	2	2	2	2					
	JD															1	1	1	1	1	1					
T2.3	SD																					1	1	1	1	1
	JD																					2	2	2	2	2
T3.1	SD	3	3	3	3	3	3	3																		
	JD	3	3	3	3	3	3	3																		
T3.2	SD								2	2	2	2	2	2	2	2	2	2	2	2						
	JD								1	1	1	1	1	1	1	1	1	1	1	1						
T3.3	SD																				5	5	5	5	5	5
	JD																				3	3	3	3	3	3
T4.1	SD																									
	JD																									
T4.2	SD																									
	JD																									
T4.3	SD																									
	JD																									
Resources																										
	SD	7	7	7	7	7	7	5	4	5	5	5	5	4	4	6	6	6	6	6	8	6	6	6	6	6
	JS	5	5	5	5	5	5	5	3	5	5	5	5	4	4	5	5	5	5	5	6	5	5	5	5	5
Additional resources																										
	SD								1												2					
	JD								2												1					

Weeks		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Tasks																										
T1.1	SD																									
	JD																									
T1.2	SD																									
	JD																									
T1.3	SD																									
	JD																									
T2.1	SD																									
	JD																									
T2.2	SD																									
	JD																									
T2.3	SD	1	1	1	1	1	1	1																		
	JD	2	2	2	2	2	2	2																		
T3.1	SD																									
	JD																									
T3.2	SD																									
	JD																									
T3.3	SD	5	5	5	5	5	5	5	5																	
	JD	3	3	3	3	3	3	3	3																	
T4.1	SD									4	4	4	4	4	4	4	4	4	4	4	4	4	PROJECT			
	JD									3	3	3	3	3	3	3	3	3	3	3	3	3	BUFFER			
T4.2	SD								1	1	1	1	1	1	1	1	1									
	JD								2	2	2	2	2	2	2	2	2									
T4.3	SD																	1	1	1						
	JD																	2	2	2						
Resources																										
	SD	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	4	4	0	0	0	0
	JS	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	3	0	0	0	0
Additional resources																										
	SD																									
	JD																									

Figure 3: Project resources allocation

b At week 19 resources are acquired and released the week after. As a consequence the project incurs in an additional cost in relation to 2 additional weeks for senior develpers and one for junioner developers

c At week 19 the required effort for senior developers is 8 so a senior developer will have to be recruited with an additional cost of 15.000€and similarly for junior developers

In summary it is necessary to consider 3 additional weeks for SD, 3 additional weeks for JD and 15.000€for recruitment activities. We can derive the total cost of the project considering an effort of 261 ($Total\ SD\ Effort$) weeks for SD (total+3) and 226 ($Total\ JD\ Effort$) for JD (total +3):

$$(\textit{Total SD effort} \times 2000 + \textit{Total JD effort} \times 1500) \times 1.5 + 30.000 = (522.000 + 339.000) \times 1.5 + 30.000 = 1.321.500€$$

2. In order to optimize the total cost it is possible to revise the plan anticipating of a single week tasks T1.3, T2.2, T2.3, T4.1, T4.2. The resulting effort distribution if reported in Figure 4. As it can be observed from the figure the only additional cost to consider now is one additional week both for SD and JD. So now the $Total\ SD\ Effort = 259$ and $Total\ JD\ Effort = 224$. Therefore the total cost in this case is:

$$(\textit{Total SD effort} \times 2000 + \textit{Total JD effort} \times 1500) \times 1.5 = (518.000 + 336.000) \times 1.5 = 1.281.000€$$

Solution when and effort of 57 is considered for JD in relation to T1.2

In case the effort considered for T1.2 in relation to JD is 57 the following changes apply with respect to what is reported above:

- **No Optimization**
  - the effort needed by T1.2 for each week, in relation to JD, will be 8,13. The result is that in any case we need to recruit 8 JD. In total we will need to recruit 1 SD and 8 JD for a total cost of 15.000€×9 = 135.000€
  - In this case only 2 additional weeks for JD are needed since at week 19 there is not a peak in the demand of resources. So in this case $Total\ SD\ Effort = 261$ as above, while $Total\ JD\ Effort = 275$

Weeks		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Tasks																										
T1.1	SD	2	2	2	2	2	2																			
	JD	0	0	0	0	0	0																			
T1.2	SD													1	1	1	1	1	1	1						
	JD													1	1	1	1	1	1	1						
T1.3	SD								1	1	1	1	1	1	1	1	1	1	1	1						
	JD								2	2	2	2	2	2	2	2	2	2	2	2						
T2.1	SD	2	2	2	2	2	2	2	2	2	2	2	2													
	JD	2	2	2	2	2	2	2	2	2	2	2	2													
T2.2	SD														2	2	2	2	2	2						
	JD														1	1	1	1	1	1						
T2.3	SD																				1	1	1	1	1	1
	JD																				2	2	2	2	2	2
T3.1	SD	3	3	3	3	3	3	3																		
	JD	3	3	3	3	3	3	3																		
T3.2	SD								2	2	2	2	2	2	2	2	2	2	2	2						
	JD								1	1	1	1	1	1	1	1	1	1	1	1						
T3.3	SD																				5	5	5	5	5	5
	JD																				3	3	3	3	3	3
T4.1	SD																									
	JD																									
T4.2	SD																									
	JD																									
T4.3	SD																									
	JD																									
Resources																										
	SD	7	7	7	7	7	7	5	5	5	5	5	5	4	6	6	6	6	6	6	6	6	6	6	6	6
	JS	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5

Weeks		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Tasks																										
T1.1	SD																									
	JD																									
T1.2	SD																									
	JD																									
T1.3	SD																									
	JD																									
T2.1	SD																									
	JD																									
T2.2	SD																									
	JD																									
T2.3	SD	1	1	1	1	1	1																			
	JD	2	2	2	2	2	2																			
T3.1	SD																									
	JD																									
T3.2	SD																									
	JD																									
T3.3	SD	5	5	5	5	5	5	5	5																	
	JD	3	3	3	3	3	3	3	3																	
T4.1	SD									4	4	4	4	4	4	4	4	4	4	4	4	4	PROJECT			
	JD									3	3	3	3	3	3	3	3	3	3	3	3	3	BUFFER			
T4.2	SD							1	1	1	1	1	1	1	1	1										
	JD							2	2	2	2	2	2	2	2	2										
T4.3	SD																1	1	1							
	JD																2	2	2							
Resources																										
	SD	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	4	4	4	0	0	0	0
	JS	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	3	3	0	0	0	0

Figure 4: Project resources allocation

- the resulting cost is given by the following formula:
  $(\textit{Total SD effort} \times 2000 + \textit{Total JD effort} \times 1500) \times 1.5 + 135.000 = (522.000 + 412.500) \times 1.5 + 135.000 = 1.536.750€$

- **Optimized**
  - the same optimization reported above can be applied here. The result is that 8 additional JD are in any case needed but there is no need for an additional SD. The cost for recruitment activities will be 15.000€×8 = 120.000€
  - There is only an additional week that has to be added in relation to SD at week 12. So in this case $Total\ SD\ Effort = 259$ as above, while $Total\ JD\ Effort = 273$.
  - the resulting cost is given by the following formula:
    $(\textit{Total SD effort} \times 2000 + \textit{Total JD effort} \times 1500) \times 1.5 + 120.000 = (518.000 + 409.500) \times 1.5 + 120.000 = 1.511.250€$