Buying time in software development: how estimates become commitments?

Supplementary materials: categories and codes

In the current document, we present the categories, their associated codes, and supporting quotes for the research question: **RQ - How are software estimates used to establish software development commitments?** We also show the categories, codes, and their relationships through figures, created in the form of networks in Atlas.ti 8. In the figures, the categories are the rectangles marked up with "[category]", while codes are the rectangles with no marking. The relationships are represented through arrows and can be of three different types:

- "is associated with" - bidirectional relationship. Both concepts are connected somehow;
- "is a" - unidirectional relationship. The concept at the beginning of the arrow is an instance of the concept at the end;
- "is cause of" - unidirectional relationship. The concept at the beginning of the arrow causes the concept at the end;
- "is part of" - unidirectional relationship. The concept at the beginning of the arrow is a component of the concept at the end.

For each figure, there is a table presenting the codes and some of its supporting quotes.

Defensible estimates

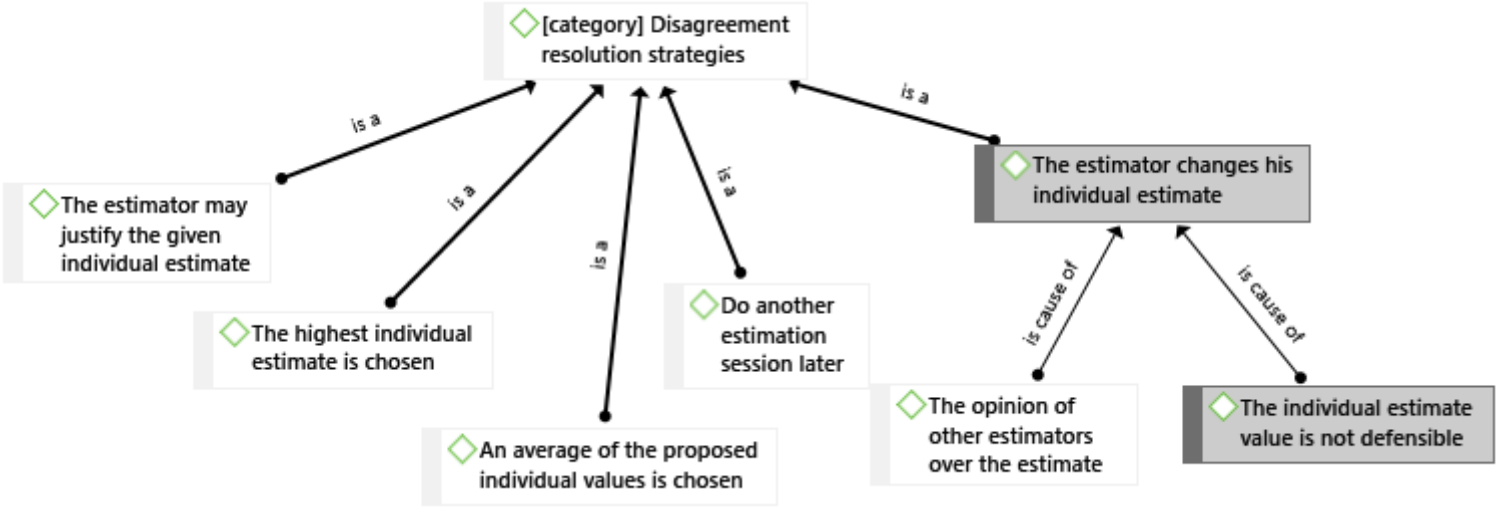

Figure 1 - Defensible estimates network

Table 1 - Codes and categories for disagreement resolution

Code	Description	Supporting quotes
[category] Disagreement resolution strategies		
The estimator may justify the given individual estimate	When the team leader or other team member disagrees with an individual estimate, the estimator who gave it explains its rationale.	"*Each one [of the estimators] says their value. If anyone disagrees, they have to explain their estimates.*" P10 (software/business analyst)
The highest individual estimate is chosen	When the team leader or other team member disagrees on the estimate, they choose the highest one among all the individual estimates.	Answering the question: "*In some moments of the estimation sessions, the team members did not agree about an estimation value. In such situations, how is the final estimation value defined?*": "In general, if the highest value is not too large, we choose it." P8 (software developer)

An average of the proposed individual estimates is chosen	When the team leader or other team member disagrees on the estimate, they choose the average among all the individual estimates.	“P13 listed all the classes he remembered and concluded that the task would take at least one ideal day of work, depending on the person who will execute the task; P14 agreed with him; P15 said that in his opinion, it would take two days; P13 reaffirmed that his estimate was contingent on the person executing the task; P14 commented that they always pad a little. However, P3 said that this week there is no room for padding. P20 estimated one day for testing. P3 said he would count one day and a half to test because of other stuff, which is also necessary to verify. In the end, the estimate for development only was one day and a half.” - Estimation session from Team B
Do another estimation session later	When the team leader or other team member disagrees on the estimate, they have another estimation session at another time to seek agreement.	“*If there is no consensus during the estimation meeting, the involved ones get together in another moment and talk again*.” P6 (technical team leader)
The estimator changes his individual estimate	When the team leader or other team member disagrees on the estimate, the estimator who gave it changes his/her individual estimate. Often, the change is to a more optmistic value.	“P21 estimated three days, but P20 said it was too much. So P21 estimated one day and a half. (...) P20 agreed with one day and a half.” - Observation session from Team B “*When you give a too high estimate, the other ones ask you things like: “what about this?” or “did you think of that?*”. That is when it [the estimate] can change.” P11 (software developer)
The opinion of other estimators over the estimate	When the opinion of other team members over an estimate - often considering it to be too high - leads the estimator who gave it to change the value	“P21 estimated three days, but P20 said it was too much. So P21 estimated one day and a half. (...) P20 agreed with one day and a half.” - Observation session from Team B Note: both P21 and P22 are software developers.
The individual estimate value is not defensible	Suppose the team leader believes that the chosen internal team estimate is indefensible to customers or higher management. In that case, one or more of the estimators change their individual estimate - leading to a change in the internal estimate.	P16: “*I believe it takes three to four days to fully develop because for each period of the day developing for the web, I take two periods developing for the mobile platform*.” (...) P17, regarding software testing: “*It takes four days in total. Two days for local testing and two days for beta testing, because we have to evaluate the impact on Y*”. P4 made a totalization, registering it would take five days for backend

		development, plus five days for frontend development (in parallel with the backend), plus four days for testing - therefore, nine days in total; P4: "*I'll wait for the confirmation of the frontend development estimate. But you have to give it to me today*." Next, thinking aloud: "*But I don't know whether I can defend nine days*..." So, P17 answered that it could be one day and a half for each test type. Then P4 said: "*well… I can defend for eight days*!" - Estimation session from Team A "*Some estimates that software developers give me that have too much padding, then I don't buy it. So, if they don't convince me, I won't be able to defend it. If they explain it to me during the estimation session and it makes sense, I accept it. (…) So, a defensible estimate to me has a lot to do with the task complexity. I ask myself: are there many business rules involved in this task? Is there anything like this we have done before? If it is too novel or difficult, we must understand it and build the logic behind it with the team to inform the scope description*." P4 (team leader)

Padding scenarios

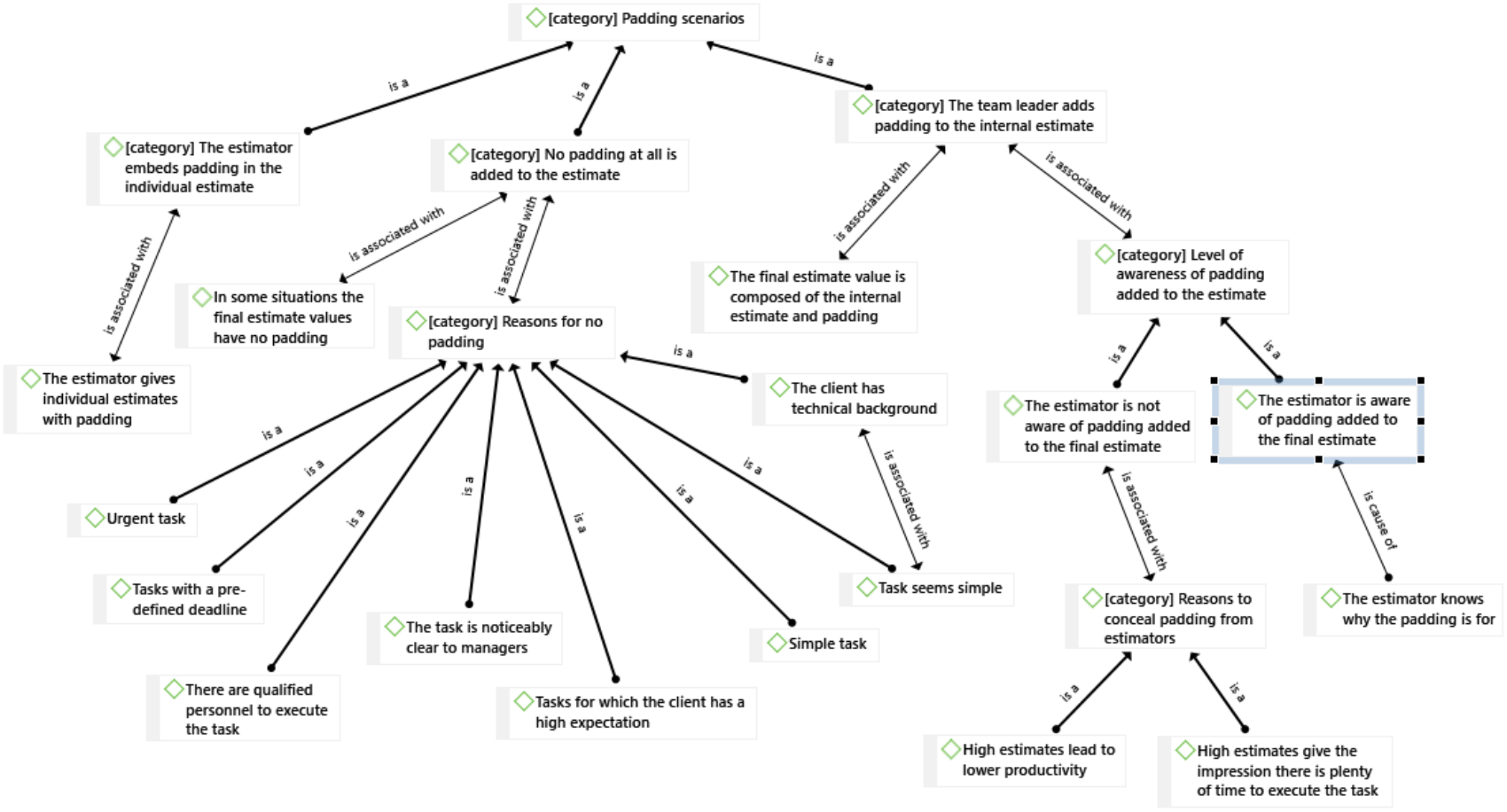

Figure 2 - Padding scenarios network

Table 2 - Codes and categories for the padding scenarios

Code	Description	Supporting quotes
[category] The estimator embeds padding in the individual estimate		
The estimator gives individual estimates with padding	When presenting the individual estimate to the team during the estimation session, the estimator embeds padding in it. In general, other team members and the team leader are unaware of such padding.	"*Every developer has his estimation method. I believe we all add padding internally, but no one talks about it.*" P11 (software developer) "*The software developer wants to work without pressure. I receive lots of estimates with padding from them. It is rare to get an estimate of something to be done in one hour.*" P4 (team leader)
[category] The team leader adds padding to the internal estimate		
The final estimate value is composed of the internal estimate and padding	The team leader adds padding to the internal team estimate, thus generating a padded final estimate which turns into the commitment with the customer.	"*So I take the team`s estimates, and I add some padding - one or two days if the task is small and up to five days if the task is large - because the team is too inexperienced. (...) I always consider whether the person giving me the estimate is more optimistic or pessimistic. (...) In my team, we have a super optimistic fellow. So, we need to add more padding before giving the customer the estimate.*" P3 (team leader) "*Besides, I always take the estimate they [the developers] give me and add some padding later.*" P4 (team leader)
[category] Level of awareness of padding added to the estimate		
The estimator is aware of padding added to the final estimate	The team leader lets the members responsible for estimating (estimators) to know that the final estimate is padded. In general, the team leader makes the team aware of why they padded the estimate.	"P13 listed all the classes he remembered and concluded that the task would take at least one ideal day of work, depending on the person who will execute the task; P14 agreed with him; P15 said that in his opinion, it would take two days; P13 reaffirmed that his estimate was contingent on the person executing the task; P14 commented that they always pad a little. However, P3 said that this week there is no room for padding. P20 estimated one day for testing. P3 said he would count one day and a half to test because of other stuff, which is also necessary to verify. In the end, the estimate for development only was one day and a half." - Estimation session from Team B

		"P4 said: "*let's talk to P19, to confirm whether it really takes only two days (...) I am also padding a bit for you on this estimate*." - Estimation session from Team A
The estimator is not aware of padding added to the final estimate	The team leader hides the padding added to the final estimate from the members responsible for estimating (estimators). Therefore, team members are led to believe that the commitment with the customer is on their internal team estimate.	"*If the team tells me they are spending six days on it, I say we will spend more - inside acceptable limits. And I do not tell the developers of the padding I added.*" P4 (team leader) "*The padding comes later. (...) If I estimate I will spend four days on a task, they consider that I am now in the company for two years. Some people are here for a few months only, so P3 always says we must take it easy. Therefore, I believe P3 adds padding later, but it is not of our concern. (...) During the meetings, they told us that the padding is to raise the confidence of the team leader with the customer.*" P8 (software developer) Note: P3 is a team leader.
[category] Reasons to conceal padding from estimators		
High estimates lead to lower productivity	The team leader conceals the final estimate's padding due to a belief that if the team members know about it, they will be less productive.	"*Suppose the estimate is 30 days. People see this as a high value. They go to the toilet numerous times; they watch propaganda over the internet, go to the coffee machine… when they realize, the day is over. The estimate gives the impression that there is much time to execute the task*." P6 (technical team leader)
High estimates give the impression there is plenty of time to execute the task	The team leader conceals the padding of the final estimate believing that the padded value gives the team members the feeling that there is plenty of time for executing the task. Such a feeling may lead them to distractions and less productivity.	
[category] No padding at all is added to the estimate		
In some situations the final estimate values have no padding	The team leader takes the internal team estimate as the final estimate, thus turning an unpadded estimate into the commitment with the customer.	Answering the question "In which situations padding estimates is not possible?": "*In simpler cards. We know what to do, so it is hard for everyone to accept it [the padding]. It depends a lot on the complexity*." P7 (software developer) "*If the CEO says the project is noticeably clear regarding what we have to do, and if we have qualified personnel, we can not pad*." P10 (software/business analyst)

[category] Reasons for no padding		
Urgent task	When the team has to work fast to satisfy a pressing need, the team leader cannot pad the final estimate value.	"*In urgent situations, it is also impossible to pad.*" P3 (team leader)
Tasks with a predefined deadline	When the task has a predefined deadline, padding the schedule estimate is impossible.	Answering the question "In which situations padding estimates is not possible?": "*Another case is when the task is a promise from our board of directors. We receive them closed, with a defined deadline.*" P3 (team leader)
There are qualified personnel to execute the task	When the company has people qualified for executing the task, higher management does not accept padding.	"*If the CEO says the project is noticeably clear regarding what we have to do, and if we have qualified personnel, we can not pad*." P10 (software/business analyst)
The task is noticeably clear to managers	When there is low uncertainty on needs and requirements, padding the final estimate value is not possible.	
Tasks for which the client has a high expectation	If the client has a high expectation on the task, fast delivery becomes a priority, and padding the final estimate value is not possible.	Answering the question "In which situations padding estimates is not possible?": "*Also, in tasks in which the customer has high expectations, we can not make late deliveries. Those are the cards that lead us to overtime work.*" P3 (team leader)
Simple task	When the task is too simple, padding the final estimate value will not be accepted.	Answering the question "In which situations padding estimates is not possible?": "*In simpler cards. We know what to do, so it is hard for everyone to accept it [the padding]. It depends a lot on the complexity*." P7 (software developer)
Task seems simple	If the task is complicated, but people outside the project like customers or higher management, consider it simple, padding the final estimate value will not be accepted.	Answering the question "In which situations padding estimates is not possible?": "*In situations where an outsider would consider the card to be simple, but the implementation is like "may God help us." For instance, module W's code is quite tricky because there is an impact in many other parts of the system. However, from the perspective of the customer, it's simple.*" P3 (team leader)
The client has technical background	If the customer has technical knowledge and experience, they may not accept padded final estimate values, especially for more straightforward tasks.	"*We also consider who the customer is because sometimes he has a technical background and will not accept padding, depending on the task. If the task is about labeling a field, he won't accept padding at all.*" P3 (team leader)

Reasons to pad

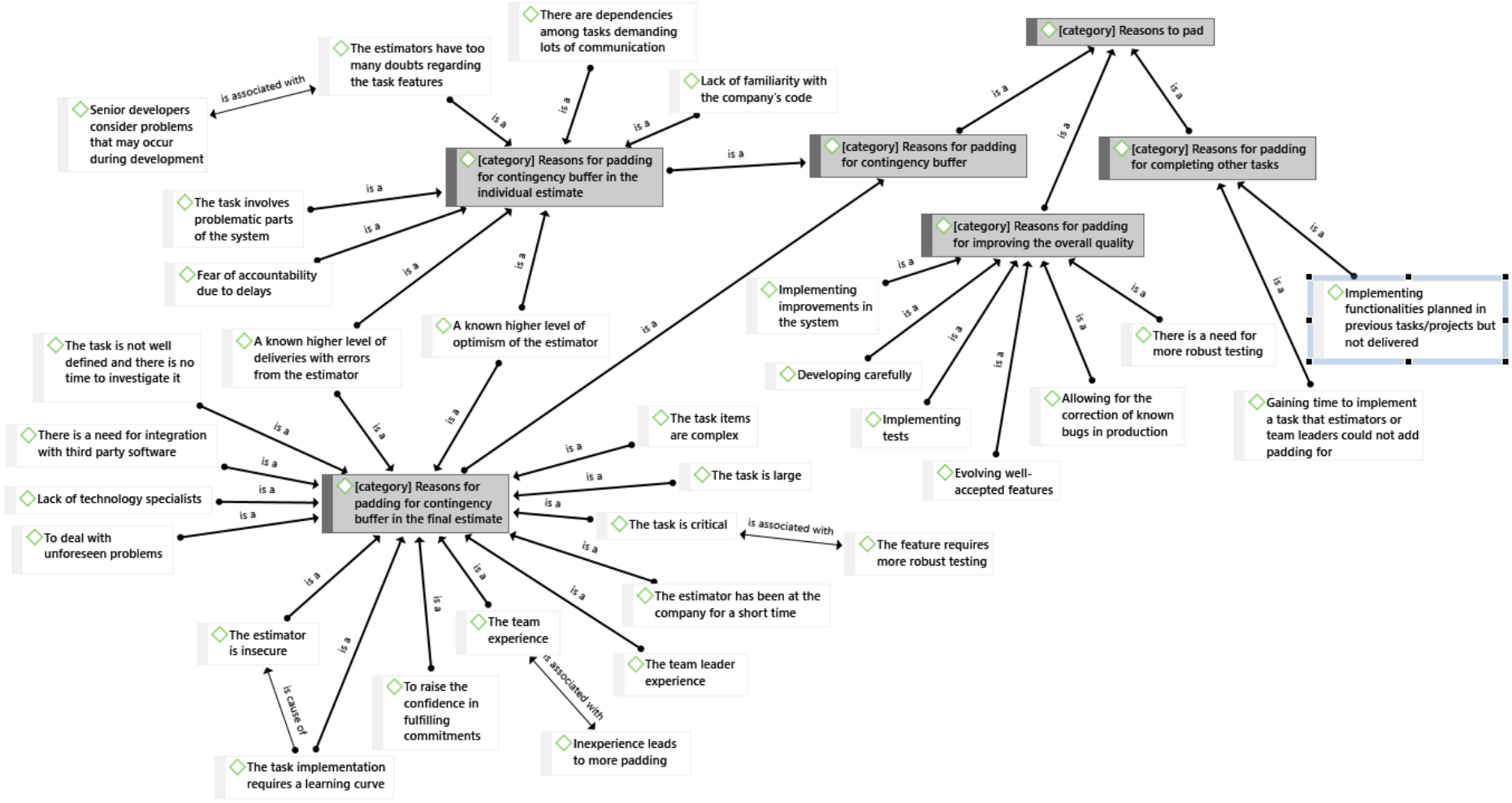

Figure 3 - Reasons to pad network[1]

[1] The categories representing the reasons are in gray to improve readability.

Table 2 - Codes and categories for the reasons to pad - only categories directly related to codes are included

Code	Description	Supporting quotes
[category] Reasons for padding for contingency buffer in the individual estimate		
Lack of familiarity with the company's code	The team member responsible for estimating (the estimator) does not know much about the code, because he or she is new in the company.	"*Every developer has his estimation method. I believe we all add padding internally, but no one talks about it. As I am an optimistic fellow, I always pad, but I don't talk about it. (...) Especially at the beginning of projects. When I am at a new company, as I am not familiarized with their code, I add a high value of padding*" P11 (software developer)
There are dependencies among tasks demanding lots of communication	The team member estimates a task that depends on another one else in the team is estimating. Therefore, it is uncertain to some degree. The estimator believes they will need much communication with each other to execute the task.	"*If a feature depends on another, that other person will implement and which we are also estimating, we add padding. If there is a lot of back-and-forth communication...*" P11 (software developer)
The estimators have too many doubts regarding the task features	The team member responsible for estimating the task has difficulties understanding it thoroughly and expresses many doubts regarding it during the estimation session.	"*The senior developer gives higher values because he thinks in an intermediary situation: 90% of what can go wrong and the rest is about what can go right. If a task is too simple, we think 100% on the happy scenario. If it is something that many people have questions about, we think about what can go wrong*." P6 (technical team leader)
Senior developers consider problems that may occur during development	Senior developers can ponder about what can go wrong during the execution of the task. Therefore, they tend to embed padding to deal with them, especially if they realize other less experienced team members are uncertain about the task.	
The task involves problematic parts of the system	The estimator believes the task requires dealing with some specific parts of the system, which are more complicated.	When questioned about why software developers give higher estimate values: "*Usually, it is because we are afraid of the problems we will have to face. Like, in larger tasks or tasks that involve implementation in some specific parts of the*

	They know the chances of finding a more challenging to solve problem is high and need to consider in their estimates.	*system, which have higher chances to have a problem there*." P8 (software developer)
Fear of accountability due to delays	The estimators know they will be held accountable for delays, so they consider this in their estimates.	"*We [team leaders] do not pad. Developers do, because of fear. If they finish the task late, I'll ask them what happened, and they fear that.*" P2 (team leader)
A known higher level of deliveries with errors from the estimator	The task the team member is estimating depends on another task on the responsibility of another team member. The estimator believes this other team member delivers lower quality than required, leading to rework before the final delivery. Therefore, the estimator takes this into account in his/her individual estimate.	"*I always consider who is going to develop the backend for me. Because some people deliver with more errors or who deliver without documentation, so there will be more conversation with this person.*" P11 (software developer)
A known higher level of optimism of the estimator	The estimator believes he/she has a bias for underestimating tasks. Therefore, he/she embeds padding to the individual estimate because of this characteristic.	"*Every developer has his estimation method. I believe we all add padding internally, but no one talks about it. As I am an optimistic fellow, I always pad, but I don't talk about it. If I think it takes one day, I will say it takes three. Some people may do it for slacking, but I do it because of my optimism since I have already had trouble giving lower estimates. Especially at the beginning of projects. When I am at a new company, as I am not familiarized with their code, I add a high value of padding*" P11 (software developer)
[category] Reasons for padding for contingency buffer in the final estimate		
A known higher level of optimism of the estimator	The team leader knows that the estimator who provided the individual estimate value has an underestimation bias. Therefore, he/she adds padding to the final estimate value because of this estimator characteristic.	"*If the person is optimistic, we also pad*." P3 (team leader)
A known higher level of deliveries with errors from the estimator	The team leader knows that the estimator who provided the individual estimate value tends to deliver the tasks with a	"*Nowadays, I know when a task is going to return [with errors from the test] due to the experience I have with the person [assigned to the task] – then we add more padding*." P3 (team leader)

	lower quality than required, leading to rework. Therefore, he/she adds padding to the final estimate value because of this estimator characteristic.	
The task is not well defined, and there is no time to investigate it	There is a high degree regarding the task requirements, and the team has to commit before having any time to investigate more about it.	Answering the question: "In which situations did you pad estimates?": "*When we can not define the feature very well. We need to carry out feasibility studies, but there is no time to do it because it is time to make a proposal.*" P9 (team leader)
There is a need for integration with third-party software	The task requires integration with third-party software, leading to more communication and raising the chances of problems.	"When it is about the team estimate… I think everything depends of the control the team has of what is external or internal. When it involves integration with other software, that is, a dependency, it requires more communication and prioritization. It gets toilsome, and so we add more padding." - P11 (software developer)
Lack of technology specialists	When the solution requires specialized technology, and there are no qualified team members, the final estimate value is padded to include the time needed to find someone knowledgeable.	"*We work with people. After we generate the WBS, we ask ourselves: "who has the skills to do this?" We may not have someone with experience with big data, for instance. We have to count for the time to train the person for that. We always consider the knowledge of the technology, whether we have a specialist on it… And we include the time it takes to find someone*." - P10 (software/business analyst)
To deal with unforeseen problems	Since the team cannot predict all problems they may find during task execution, they pad the final estimate value to deal with unforeseen problems and raise the chance of fulfilling commitments.	"*So, If I say something takes three days, the team define as one week, because if there is a problem, we have time to solve it*." P12 (software developer)
The estimator is insecure	The estimator is unsure which individual estimate value to give because they are inexperienced on the task.	*"P18: "the problem for me is that it is hard to test these reports, from what I realized the other time."* P17 explained a little about how they executed software testing the other time. P4 commented that it had been a long time since they have implemented that kind of functionality and, so there may be a learning curve involved. Then he asked: *"what is the deadline?"* P18 asked P17: *"Do you know how long P19 took to implement this the last time?" (...)*
The task implementation requires a learning curve	The estimator - who probably is going to be responsible for executing the task also - is inexperienced on the task and needs a lot of learning about it.	

		They tried to remember how long P19 took to implement it, and then P17 said: *"Give it two days."* P4 then said: *"Let's try to talk to P19, to find out whether it takes two days. I will tell him to work with you on this functionality so that you learn more about it. This way, we won't have this knowledge concentrated in one person only. After all, we may have to implement this kind of feature again, right? I am also padding a bit for you on this estimate."* - Estimation session from Team A
To raise confidence in fulfilling commitments	The estimate is padded to raise the chances that the team will satisfy established commitment.	"*During the meetings, they told us that the padding is to raise the confidence of the team leader with the customer. They don't convert the padding to the team - at least it is what they said in the meeting. If the developer estimates five days during the estimation session, he has five days to finish the task.*" P8, Software Developer
The team experience	The experience the team has with the product or with software development in general.	"*So I take the team`s estimates, and I add some padding - one or two days if the task is small and up to five days if the task is large - because the team is too inexperienced*." P3 (team leader)
Inexperience leads to more padding	The higher the team inexperience, the higher the padding added to the internal team estimate.	
The team leader experience	The team leader experience with team members and overall software development experience.	"*Nowadays, I know when a task is going to return [with errors from the test] due to the experience I have with the person [assigned to the task] – then we add more padding*." P3 (team leader) When asked about how the sizing of padding is defined: "By experience." P4 (team leader)
The estimator has been at the company for a short time	Since the estimator may not be responsible for executing the task, the team leader has to consider that some less experienced person may be responsible for executing it. Therefore, padding is essential for keeping commitments.	"*If I estimate I will spend four days on a task, they consider that I am in the company for two years now. Some people are here for a few months only, so P3 always says we must take it easy. Therefore, I believe P3 adds padding later*" P8 (software developer)
The task is critical	There is a high risk for errors in the task,	"*In high risk cards, if the developer asks me to add one more day for testing, I do*

	and therefore it is considered critical.	*it*.” P2 (team leader)
The feature requires more robust testing	The task is critical, and it is advisable to work hard on testing it. Therefore, more padding for testing is wise.	
The task is large	The team leader considers the task large enough to be more challenging and, possibly, more problematic.	“*So I take the team`s estimates, and I add some padding - one or two days if the task is small and up to five days if the task is large - because the team is too inexperienced*.” P3 (team leader)
The task items are complex	The team leader considers the task items challenging.	When asked about how the sizing of padding is defined: “By experience. What is the module? What are its items and their complexity?” P4 (team leader)
[category] Reasons for padding for improving the overall quality		
Implementing improvements in the system	Refactoring portions of the system.	“*When we are making the team estimates, we think of the improvements we can make to the system. Moreover, the padding is used for this also, for implementing these improvements*.” P6 (technical team leader)
Developing carefully	Executing a software development task with no hurries, for reducing the chances of delivering with errors.	Answering the question about which situations padding is justifiable: "*It is basically for testing more a card or testing a different flow. Another situation is to make things carefully, calmly*.” P2 (team leader)
Implementing tests	Implementing and executing test activities for reducing the chances of delivering with errors.	“*Another situation is when we have to implement tests… unit tests… integration tests… then we pad. Because each day coding, we are taking at least half a day implementing the tests.*” P11 (software developer)
Evolving well-accepted features	Improving features previously released to users and which were well accepted by them, giving them a higher quality feature.	“For instance, we release simplified features. If the public accepts them well… we look at their comments, we ask for the support team which features the public is questioning about… if we have this, we will release an improved version of that feature. So we estimate the release of the MVP of the feature. But we may need to make something improved later, so we add padding for this feature.” P12 (software developer)
Allowing for the correction of known bugs in production	Correcting bugs in production, which the team knows about, but had no time to correct before.	“*It also happens that there are errors we know, and we add one day in one task to correct it. For instance, we delivered functionality T, but we were not able to test it. After we delivered, the testers started to work, and they found lots of bugs.*

		Now we are correcting these bugs." P3 (team leader).
There is a need for more robust testing	The team knows the task requires careful testing, and the team leader adds padding to the internal estimate for it.	"*For instance, the card for feature W, we estimated three to five days for implementing it, and we informed seven days to the client. (...) We had to consider we need to give time for the testers to work. So this is an example of a card where we had to add more padding than needed*." P3 (team leader) "*If it's a refactoring and there are few tests on the base, we add some buffer and notify the QA team*." P11 (software developer)
[category] Reasons for padding for completing other tasks		
Gaining time to implement a task that estimators or team leaders could not add padding for	The padding of one task is used for executing another task, for which the estimate was not entirely realistic or for which padding was impossible.	"*We may use padding to gain time for a task that we could not add padding or to fix bugs. We gave an estimate of 30 working days for functionality Y, but we are counting on the padding of other tasks to finish it.*" P3 (team leader)
Implementing functionalities planned in previous tasks/projects but not delivered	The padding of one task is used for executing another task. This another task was supposed to be delivered in previous projects or iterations but was not.	"*Sometimes, we have a contract including functionalities A, B, C and D, but we do not deliver D, for instance. So, we will implement D in another project, which includes other requirements, and we add padding for D.* " - P10 (software/business analyst)