MASTERING AGILE TRANSFORMATION

BUILDING AGILE COMPETENCE BASED ON TRAINING AND BUDGET ALLOCATION

European Master in System Dynamics
Geo SD 304 – System Dynamics Modelling Process
Professor Birgit Kopainsky
Hand-in Date 21.12.2022
Handed in by: Benedikt Tusch
benedikt.tusch@student.uib.no

UNIVERSITY OF BERGEN

1. PROBLEM DESCRIPTION

Many companies, especially in the software development sector (Orłowski, Ziółkowski, and Paciorkiewicz 2017, 1), face an ever changing, uncertain, volatile environment in which they must operate. This is often referred to as the VUCA world (volatile, uncertain, complex and ambiguous). One typical response to this environment is an organizational restructuration and a shift in the style of working towards more agile approaches (Bundtzen and Hinrichs 2021, 1; Glaiel, Moulton, and Madnick 2014; Bannik 2014). These methods are prone to enable people to adapt early and successfully to changing environments.

Agile methods are numerous, and this topic has to be simplified for the scope of this paper. Therefore, I use agile methods (and their introduction here also referred to as agile transformation) as a very generic and board term referring to methods like the Scrum or Kanban, which fits with the literature (Li, Moe, and Dybå 2010, 2; Cocco et al. 2011, 117). Although, the precise working of these methods may be interesting, they are not necessary to grasp the workings of the model proposed.[1]

Every change in the organization needs adaption. And while some skill building depends on the capabilities an individual has and incorporates as knowledge-"what", agile transformation is more complicated than that. Organizations need to change their whole structure and individuals do not only need to change what to do, but especially how they do things (Bannik 2014, 7–9; Goodstein and Warner Burke 1991; Schwaber 2007). The reasons for introducing an agile way of working are manyfold (Ching and Mutuc 2018, 1) and companies implementing it hope for results like higher quality, productivity, reduction in costs and improvement of value for stakeholders (Mahnic 1970, 123; Schwaber 2007; Glaiel, Moulton, and Madnick 2014; Fatema and Sakib 2018).

Yet, this is often not what organizations discover, when they start and follow along their agile transformation. One problem is, that companies stop their planned organizational change before the positive results show themselves (if they ever show them at all) (Samuel and Jacobsen 1997, 164–65; Bannik 2014). The reference mode, shown in Figure 1, for the problem here is orientated at the "intial-dip" in performance (Samuel and Jacobsen 1997)[2] and the assumed goals of high revenue and productivity described above[3]. The problem for the companies is the reduction of productivity, that does not come up again fast enough, the too low return on investment in Learning and Development (hereafter L&D) and the higher costs or reduced profit, after deciding on introducing an agile work method. Note, that therefore the reference mode is somewhat fictive, but based on valid generic considerations on the subject matter, as described above. The paper tries to show that these considerations yield the

[1] For more description of the mentioned methods see for example (Cocco et al. 2011; Hron and Obwegeser 2022; Schwaber and Sutherland 2011; Ching and Mutuc 2018; Glaiel, Moulton, and Madnick 2014; Schwaber 2007). For this paper it is not necessary to go too deep into the precise workings of the methods. It may suffice to know that adoption of agile methods like Scrum or Kanban need more than factual sklillbuilding but the commitment to change the whole mindset and structure as this is how it differentiates itself from other "skills" that can be build.

[2] This initial dip – broadly and of course in an abridged version - refers to the behavior that performance is worsening in the beginning before it gets better later on, when companies try to implement organizational change (Samuel and Jacobsen 1997)

[3] For the settings for the *desired* run see DesiredRun Scenario in Appendix C

development of an interesting model of the dynamics of "mastering the agile transformation" that may illude companies in this kind of position.

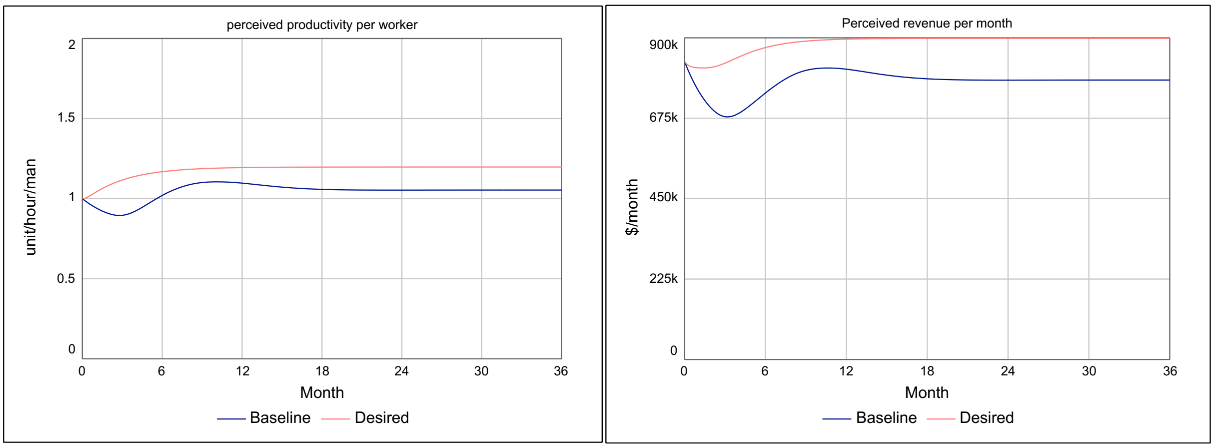

Figure 1 - Reference mode

This reference mode shows the *desired* increase of revenue per month and productivity that lies above the pre-transformation level. The baseline shows the behavior that companies could encounter and thereby stop the project after 6 or even 9 months, since it does not yield enough return. The model is fit to produce this baseline behavior

2. DYNAMIC HYPOTHESIS

The aim of the model is to illustrate the struggles companies face when taking up agile transformation and to explain why the systems behavior is deviating from what most management wishes for. This chapter provides insides in the development of the dynamic hypothesis. The next chapter is dedicated to the analysis of the developed model. The last chapters are concerned with policy, implementation and further research.

The *model boundary* is set to include some exogenous information about the company, here assumed to be aptly represented by generic values about a company in a certain size and statistical averages about cost and spending on L&D[4]. Endogenously the behavior is produced through decisions on budget, the revenue, productivity, time spent working or training and a learning sector for the skill building. Due to the scope of this paper, this entails that several factors, which are important in reality, had to be excluded from the model boundary. These include for example the inner resistance of the workforce for change, personal characteristics, the role of leadership, the precise works of interdependent learning between employees, a more complex allocation mechanism to control the amount of money the company has for L&D and the vast topic of detailed organizational learning in itself (Argote 2013). This hints to the fact, that more research is needed to include the dynamics of these factors.

General inspiration and orientation

The structure of the model and the development of the dynamic hypotheses was oriented on several influences from the literature. The model of "capability traps" elaborates on the topic of dividing time in working harder or smarter and depict the attribution errors in the misperception of these dynamics (N.P. Repenning and Sterman 2002; Nelson P. Repenning and Sterman 2002). Yet only inspiration was taken from here since agile transformation is not just a skill one develops but the whole company and their process is under construction. This

[4] For more detailed references see Appendix C – Model Documentation

is why one cannot choose in the bare sense between working in the usual way (and harder) and the agile way (working smarter).

The learning structure is oriented at literature about organizational learning and learning curve (Morrison 2008; Rahmandad, Repenning, and Sterman 2009; Argote 2013). The detail level in this literature area is very high, so several simplifying assumptions had to made (see below in the descriptions of the loops).

Last but not least, the “system dynamics model for planned organizational change” was used as inspiration for the “initial dip” behavior in the model and reference mode, that is also seen in the model by Samuel and Jacobsen (1997). Yet, as the model focus on a different boundary and endogenous factors, no explicit model structure was used from that paper.

The developed model structure is depicted in Figure 2. In what follows, the main loops of the system including assumptions and references are discussed before continuing with the analysis of the model.

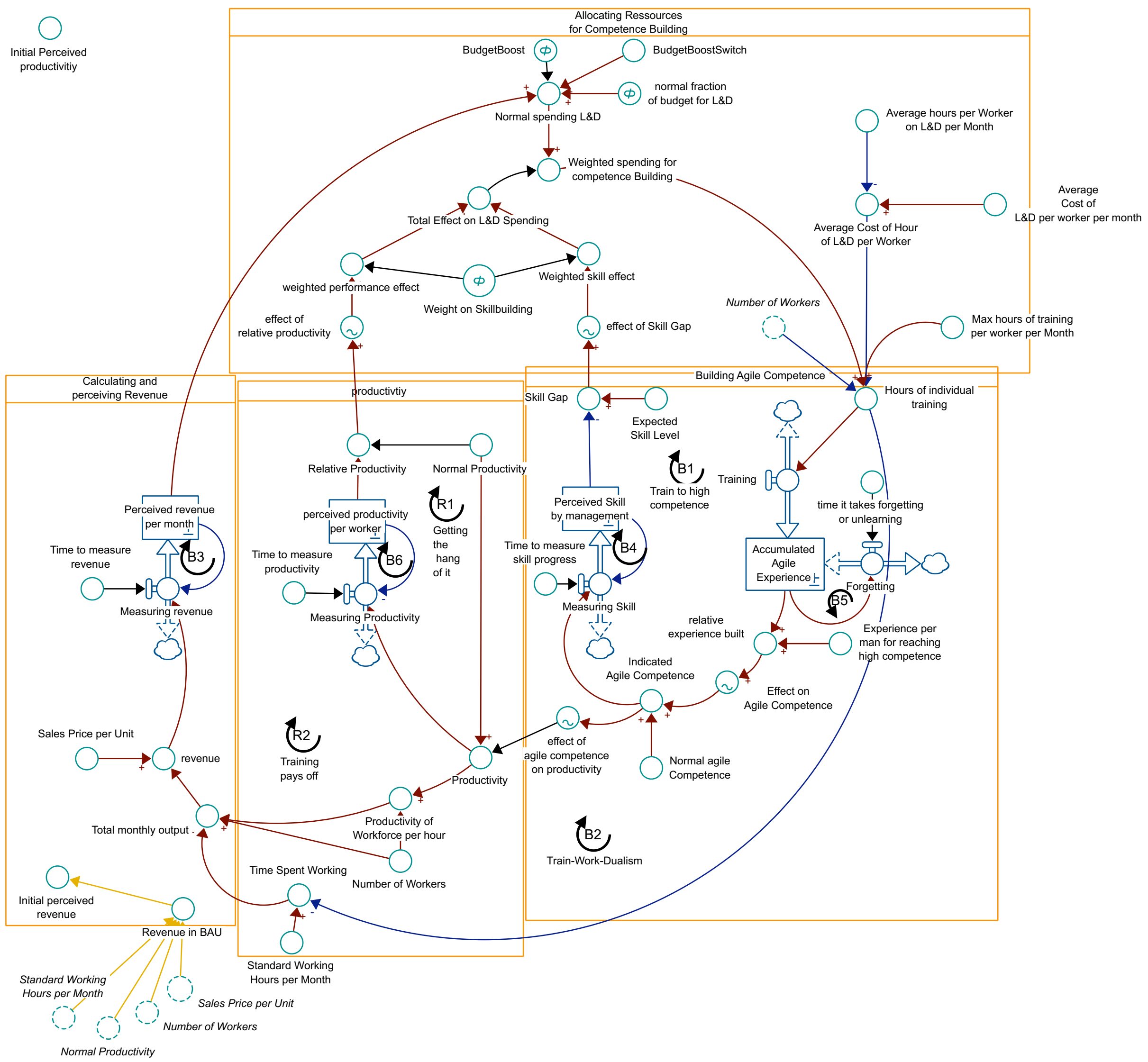

Figure 2 - Stock-Flow Diagram of the model

B1 – Train to high competence

The training flow increases the stock of accumulated experience and is influenced by the amount of training hours each employee receives in this month period. The flow represents a linear increase with a slope dependent on the amount of training hours, which corresponds to the literature (Morrison 2008, 1184–86). The accumulated experience stock keeps track of the hours of training and is drained by the forgetting flow. The forgetting structure (**B5**)[5] also corresponds to the literature and can be seen as both, the organizational forgetting via new hires and collective knowledge depreciation and the individual forgetting (Morrison 2008; Anderson and Lewis 2014; Argote 2013; N.P. Repenning and Sterman 2002). The accumulated experience gets translated to an indicated agile competence. This translation process involves on assumed and argued for effect function and threshold of how many hours account for a high competence. Note, that these assumptions are crucial for the mechanism. The threshold is based on general amounts of hours for courses and educational programs in that area and are amended with the need of a similar amount of practice hours to reach high competence (Coursera 2022b; 2022a; Scrum Alliance n.d.). The effect function translates the relative experience to an indicated agile competence. This is to depict in some form the usually used power function of the learning curve (Argote 2013; Morrison 2008). The effect is shaped in an S-form to capture the consideration that progress is slowly in the beginning until a normal value is reached (0.5*relative experience, normal agile competence). This is due to the consideration that even with some basic knowledge of agile practice employees can work pretty good but not surpass normal productivity. In the end though, making progress takes more hours of training.[6] The indicated agile competence is perceived by the management with an information delay (Hines 2015, 31) and is compared to the desired level of skill to form the skill gap. This gap is used to influence the allocation decision. If the skill gap is high, the management accounts for it with investing more of their normal spending and vice versa. The importance of the skill gap is represented with the weight, the management puts on skill building. This weight is in the baseline splits equally between skill and performance and is up to the company in each specific case. Further research for the weight value is hence needed to determine a generic value.

R1 – Getting the hang of it

The indicated competence is translated to a certain level of productivity, normalized with the normal productivity via an effect function. This is an assumed effect function and documentation for this can be found in Appendix C – Model Documentation. Once the current productivity with the current agile competence is set, the management perceives the current productivity with an information delay and compares it to the normal productivity to formulate a relative productivity. This is used to influence the budget allocation decision, again with an effect, that is weighted according to company's policy. The weight is a dual choice so the company spilts the weight fully between skill and performance. If the relative productivity is low, the effect leads to a lower investment in training, since the company knows that training will impede the time spent working and productivity and budget first needs to go up again. But the more productivity rises more budget is freed up for training. This way more productivity perceived by the management leads to more training next round.

[5] Note, that data for the fraction of forgetting is hard to come by and highly individual for every company. More research is needed to establish a more precise and sustainable value here. The value used in this model is taken from Morrison (2008) For more on the time to forget see Appendix C – Model Documentation.

[6] For more insights in these functions see model documentation in Appendix C – Model Documentation

B2 – Train-Work-Dualism

This balancing loop represents the mechanism that an increase in hours spent on training lead to less hours of training in the next round. This is because employees are confronted with a fixed number of hours they have at their disposal and that they have to make a choice between, in this model, just to options. To train or to work. Hence every hour employees train, they cannot work. This leads to a decrease in revenue per month since if they work less, selling/producing less, revenue goes down. The revenue is now used to calculate the new fraction of spending on L&D. This fraction is an assumed value, that is based on generic information about how much a company spends on learning and development (F.learning Studios 2022; Sather 2021; Sucess Coaching n.d.; American Express 2022)[7]. With less revenue per month and a fixed fraction, less money will be at the company's disposal to spend on training next month around. This balancing loop represents the structure where more training lead through reduced working hours and thereby revenue to less spending on training.

R2 – Training pays off

From the training flow we work our way once more towards productivity. The new current productivity, in respect to the current agile competence, is now being used to calculate the revenue for this months period. Since competence and productivity increases with more training, more revenue will be generated. This leads to an increase in the spending for L&D, since the fraction for L&D remains fixed by assumption. Once more money is ready for training, more training hours can be bought and allocated to each employee. The training pays itself off through the increase in productivity and revenue.

Further assumptions

For calculating the revenue and the costs of training, the model needed to establish assumptions about values like number of workers, sales price, average costs of L&D per employee per month and average amount of hours for L&D per month. Sales price and number of workers were chosen so that the results of the calculation in the model could represent the generic definition for a small-sized company, i.e. employees =< 50, monthly revenue =< 10 mio./12) (Europäische Kommision 2003). For the average numbers of cost, spending on L&D per employee and average hours spent on L&D, generic statistical values where used (Statista 2021a; 2021b).

3. ANALYSIS

Before describing the simulated base-run and policy option, the following paragraphs briefly discuss validation tests performed to establish confidence in the model structure, behavior and results.

Structure and parameter confirmation test

The structure and parameter correspond to findings in the literature, statistical averages and argued for assumptions of the author as mentioned in chapter 1 and 2. Nevertheless, confidence in the effect variables, the concept of productivity increasement due to a different way of working and values for company specific values turn out to be a sensitive and tricky issue. The model documentation in appendix C provide argumentations for assumptions on

[7] Note, that these websites do not qualify to the scientific standard. Nevertheless, they may just serve as experts' opinions to form a first educated guess on the parameters value. Further research is need. See also Appendix C – Model Documentation

these topics in addition to what was already argued for in the previous chapters. Still, further research on that structures and values are needed to present a more detailed and robust model in the future. The structure was partially tested to establish confidence. The tests did show the expected behavior.

Dimensional consistency

The model shows dimensional consistency mathematically in the equations and conceptually in terms of realistic equivalents and there are no arbitrary additions. The used simulation program Stella also reported no unit errors.

Extreme Conditions Test

Parameters and table functions have been tested through partial model testing and behave expectedly. The MIN function used to calculate *hours of training* was used to ensure that the variable keeps in a reasonable range. The effect functions were set up, so that values keep reasonable under extreme conditions.[8] Under indirect extreme conditions too, the model behaved as expected.

Integration error test

The model was tested with different integration methods (Euler, RK4) and different time intervals (1/8,1/16,1/32). The interval of 1/16 with integration method RK4 produced reliable results, that were not changed by increasing the interval to 1/32. Therefore, RK4 and a DT of 1/16 was chosen. The time horizon of 36 months was chosen to make sure the simulation covers a phase where behavior doesn't change anymore.

Behavior sensitivity test

The model behavior was tested with sensitivity analysis with 200 runs for the parameters and 5 variations of the effect variables. The results are described in detail in Appendix A – Sensitivity Analysis. The model shows to be mostly numerical sensitive under the tests and it behaves as expected within the reasonable ranges. Here, it is just mentioned that the model behaves especially sensitive (but expectedly so) towards a change in *Experience per man for reaching high competence* and effect functions that translate accumulated experience into agile competence and productivity. The reader is referred to Appendix A – Sensitivity Analysis for deeper insights in the tests. Worthy of mentioning here though is especially the parameter *weight on skillbuilding*. This can be considered as both a limitation (the value definitely needs more backup by further research) and a leverage point, since it proofs very salient for policy options. The sensitivity test showed a change in model behavior in the higher variations of the

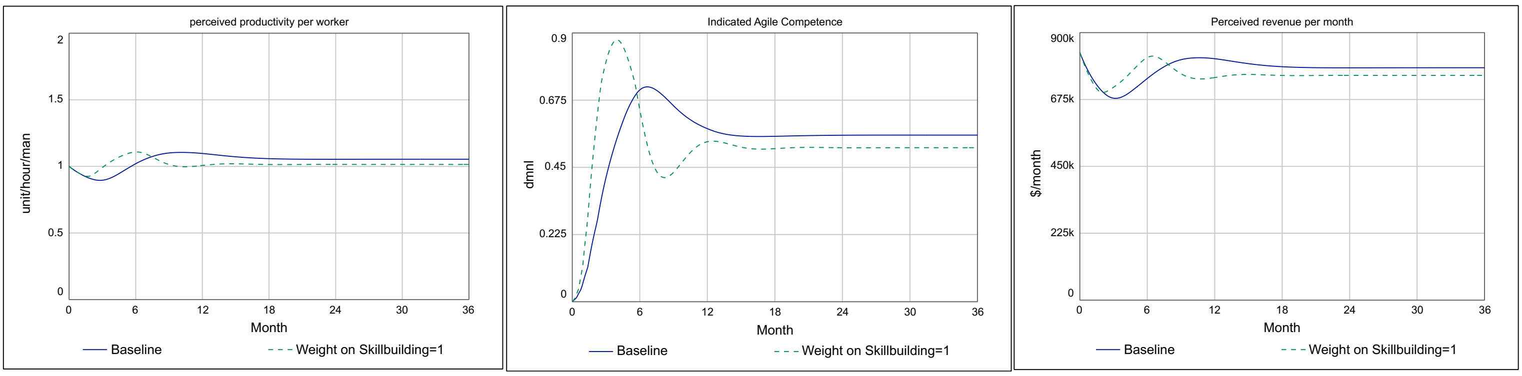

Figure 3 - Model run for Weight on Skillbuilding = 1

[8] See also Appendix C – Model Documentation for more on the parameter ranges.

parameter towards oscillatory behavior (see this in Figure 3). This is expectable since the weight empowers or weakens the *B1 -Train to high competence* balancing loop. By empowering *B1* the system responds with dampening oscillations around the equilibrium value that stabilizes itself, when amount of training holds the level with forgetting. In terms of a desired systems outcome (high revenue per month and a constant skill level) it is interesting that the model suggests that over-emphasis of the skill gap is not a promising solution.[9]

Behavior Pattern Test

The model produces the expected reference mode and could, under modified unrealistic conditions, produce the desired outcome. As the reference mode is not validated through data but fictively created from the story, the model was not calibrated towards data, but it suggests confidence as it can produce the expected/feared/desired outcomes.

Baseline Simulation

Figure 4 shows the baseline simulation of the model. Note, that for a better overview, the graph only shows behavior between 0 and 18 months (1.5 years) and not 36 months! This to better depict the changes that are happening in the beginning while providing verbal description.

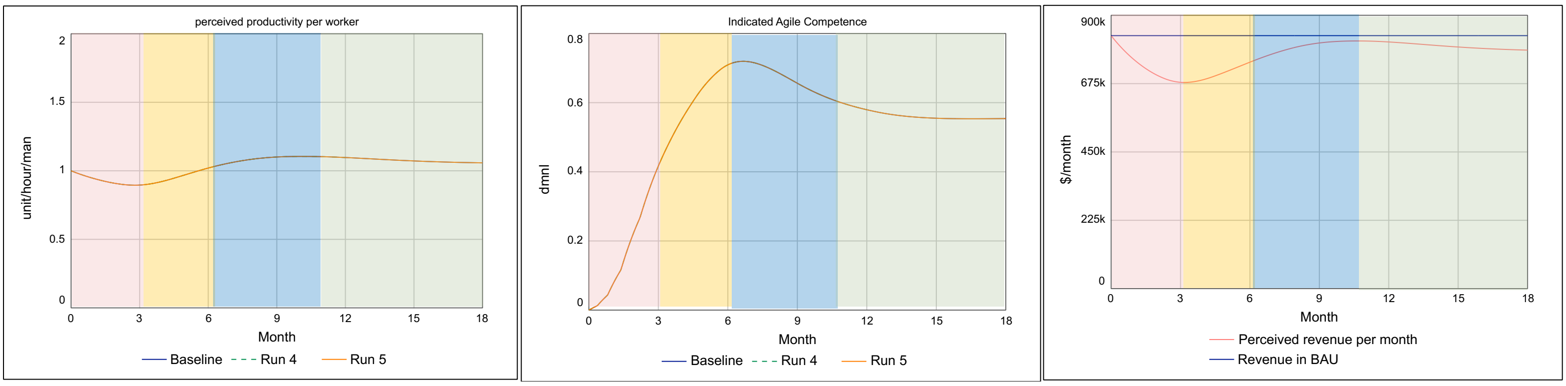

Figure 4 - Baseline simulation with time horizon 0 to 18 months

Phase 1 – light red | In the outset, the company has opted for their transformation and as perceived productivity (*pprod)* is high and the skill gap big, the training starts off real eager. As the transition in working method leads to a reduction in productivity, *pprod* gets adjusted with an information delay. The *TrainToCompetence B1* is driving the system in the beginning. Though, the *TrainWorkDualism* gets slowly stronger as in combination with the information delay for revenue the perceived profit gets adjusted downward since the workforce spends so much time for training. This *initial dip* in performance and revenue corresponds to the model behavior pattern observed and put forward with planned organizational change (Samuel and Jacobsen 1997). At the end of phase 1 the *B1*, who was working against the downpull of *R1 Getting the hang of it* and *R2 training pays off* (for now it does not payoff since productivity is down) has accomplished that the accumulated experience is so high, that agile competence surpass 0.5, the level that leads to normal productivity again.

Phase 2 – light yellow | This really brings *R1* and *R2* back in the game. Productivity is now increasing again, since employees are skilled enough to better work again. Yet, the hours they spent on training still hold back the revenue. The skill gap is slowly closing (note, the management needs 3 months to perceive the indicated agile competence), but still remains

[9] For more on the sensitivity results see Appendix A – Sensitivity Analysis

high. Yet the downward pulling *R1* is easing up and freeing budget because of the rising productivity. At the same time *R2* again leads to more money for training. The skill is developing now faster but growth is slowing down at the end of the phase because B1 is balancing the training out.

Phase 3 – light blue | *R1 Getting the hang of it* is now strong since productivity is surpassing normal productivity and freeing up allocation space for training hours. Yet, with the small skill gap, B1 is counteracting, keeping a low profile leading to dampen investment in training. The forgetting loop now leads to reduction in experience which is not recognized at first. Management sees the *pprod* high, the skill gap small and revenue is coming up. Yet, experience hours decrease, indicated agile competence is going down, while the revenue and *pprod* is at their peak. Note that even if productivity is back up, the revenue is still not above revenue with no training (BAU). This is because the amount of training the employees get make them more productive, yet these hours block a significant amount of time that is not used for generating profit. Here considerably, the project may be stopped by the management, especially if a fixed budget was allocated in the beginning, that is now used up (Bannik 2014). Although productivity is high, the company is not getting something out of it, not seeing that this problem is not the fault of the transformation itself (it actually made people more effective) but the misperception of how the revenue should develop, neglecting the time employees continue to need to guidance and training.

Phase 4 – light green | As the forgetting loop B5 continues to drain the experience agile competence continues to go down a bit. *Pprod* and revenue is following delayed to depict this decrease as productivity goes down a bit again. Towards the end the moderate skill gap and almost normal relative productivity leads to an allocation of the budget so that the hours of training per individual tend to and later keep in equilibrium with the forgetting loop – R1 and B1 are counteracting leading to R2 in balance with B2 and B5. The system comes to equilibrium as the competence level stops changing and productivity and revenue therefore keep at the same level. The company built up the skill, though not to its full potential and the continuous hours needed for maintaining the skill level keep the revenue still below the usual value.

Simulation Boost in L&D Budget

What could the company have down differently? Figure 5 shows the comparative graphs for a simulation run with the policy *Budgetboost.* All parameter values are kept, except the *BudgetboostSwitch* activated with switching it from 0 to 1 leading the L&D normal fraction to be added up with the *BudgetBoost* of 1%. The simulation depicts the policy that the company invests more of their budget from the outset. This leads to a stronger B1 in the beginning seeking high competence faster. It influences are more steep decline in revenue (more hours are spent on training in the beginning) but revenue is coming up faster. The *R2 Training pays off* is strong earlier in the simulation while R1 *Getting the hang of it* gets also strong faster, because productivity comes up again quickly. The higher budget allows for a leveling off between *R1, R2, B2* and the forgetting loop *B5* at a higher level. Not only is a higher revenue achieved earlier but it surpasses the business-as-usual scenario at around month 9. Now, the desired outcome of the transformation can be realized. The *Budgetboost* policy therefore seems to be a good possibility to achieve desired results. It needs more investment in the beginning and the first stages but pays off later. This worse-before-better also corresponds to mechanisms overserved by the literature (Rahmandad, Repenning, and Sterman 2009).

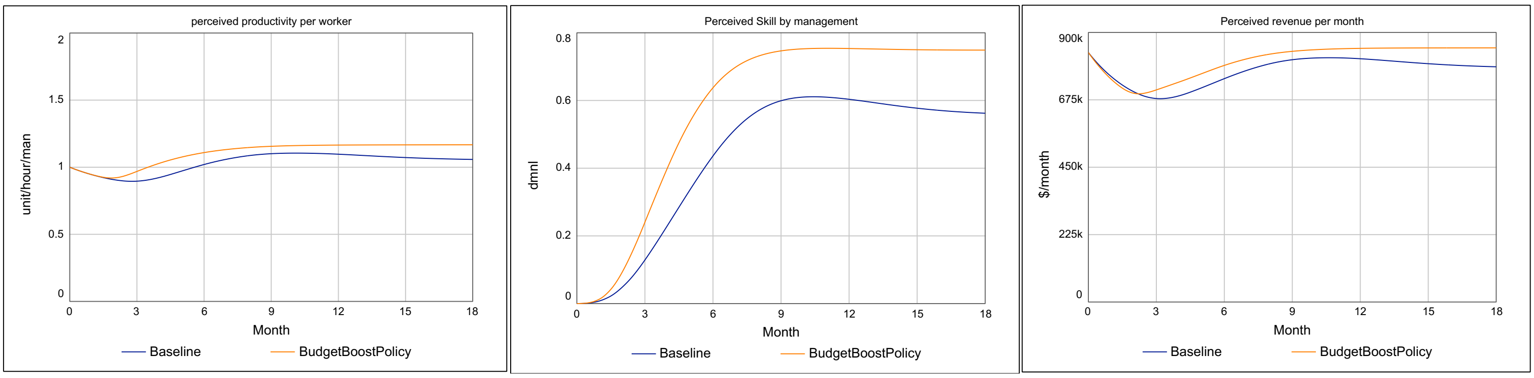

Figure 5 - Simulation run BudgetBoostPolicy

Another policy would be to vary the weight the company puts on skill building and performance. The model represents this option by allowing the *weight for skillbuilding* to be modified. As mentioned earlier in the chapter, the model shows high sensitivity to this parameter and should therefore refrain from giving clear policy recommendations based on that parameter. As can be seen in Figure 3, a complete weight on skill keeps the revenue in the long run beneath the baseline scenario. Although competence is build up very fast and early, the system reacts to this high parameter with oscillations, since the delayed balancing B1 loop is dominating. The model therefore suggests, but not proves, that a sole weight on skill building may not be the best strategy to tackle the problems at hand.

4. POLICY IMPLICATIONS AND SHORTCOMINGS

As is depicted in the paragraph above, the model supports policy implementations, for example the boost or decrease in budget or a different weight in the decision for the allocation of budget to training. It can also be sensitive to more accurate values for example the costs of consultants and trainings. These policy options are to be explored in further detail elsewhere and research on their implementation is needed, since the sensitivity of the model and assumptions only allow for tentative policy recommendations. Yet especially the boost in budget suggests promising results for making the agile transitions work. When thinking about implementations, one needs to keep in mind, that operational revenue budget is fixed and cannot be increased arbitrarily high. Whatever the company is paying for training may be cut away elsewhere. It is up to further research to identify points where higher budget allocation for Learning and Development is feasible.

Despite the reference to literature, there are of course some shortcomings, four of which may be addressed here briefly to point in the direction of further research to come. The list is not meant to be exhaustive.

Productivity and translating a new skill

The measurement of productivity is a huge area that is left to be amended by further research. How can we measure it properly? And how do we translate a new skill into effects on productivity? While this may be measured with more units/hour in some areas (increasing efficiency) this proves difficult in the topic of agile work since many agile techniques are used to create more value per product (reflecting the interest of stakeholders, being able to implement feedback fast) not the sheer number of products per se (Schwaber 2007; Schwaber and Sutherland 2011). This was tried to be avoided by claiming that even higher value products are in some sense translatable because the employee is generating more products (higher efficiency) thereby influencing the value generated. This is a simplification and more data on how to translate agile competence in increase of productivity is needed.

Training details

Although the values for training reflect values for that area, many considerations were needed to be passed aside. Do the hired consultants train the whole workforce at the same time? Is one hour of training consistent with the translation in one hour of training per employee throughout the company? If they train all at once, it may be interesting to consider how a smaller training group may yield higher effects do to a better learning experience compared to an all-train-at-once solution. These considerations though were to be left outside the model boundary but are interesting to look at in the future.

Internal resistance

There are numerous thoughts about the conditions that influence organizational change. Just one is the consideration of interdependent learning between organisations as a whole and individuals by them self. Are they competing with or hindering each other? Additionally, the whole topics of leadership, personal character traits fit for change and internal resistance to new routines and ways of working, which in reality pose a threat to every change implementation, had to be left out and are in need for further research and consideration (Wiese and Burke 2019; Schilling and Kluge 2009; Schweiger, Stouten, and Bleijenbergh 2018; Fatema and Sakib 2017)

Budget considerations and allocation decision mechanisms

The topic of deciding for a specific allocation may be influenced by much more variables than skillgap and relative productivity perception. This simplification had to be added to make the decision process feasible to model and represent. Yet more data and research are needed here, especially to formalize a generic model. It may even be interesting to keep this as a limitation and adapt to model to the specific decision-making mechanism when the model is applied to a specific company and project of change. This would render the model still sensitive to in the generic sense but would allow for consulting and support strategic decisions in the individual cases of companies.

5. CONCLUSION

Despite the shortcomings and the assumptions mentioned in the report and appendices, the model fulfills the aim of this paper, that is to provide insights in the dynamics of the agile transformation. It thereby can serve for managers to be aware of the worse-before-better behavior and the initial dip and gives at least some leverage points when thinking about a proper budget allocation for organizational change to agile ways of working. It also served as a point of departure for further research in that area. As a key message, this model suggests, that it may be better to invest more havy in the early stages of transformation, in order to build up competence quickly and ripe the benefits in the long term.

CITED WORK

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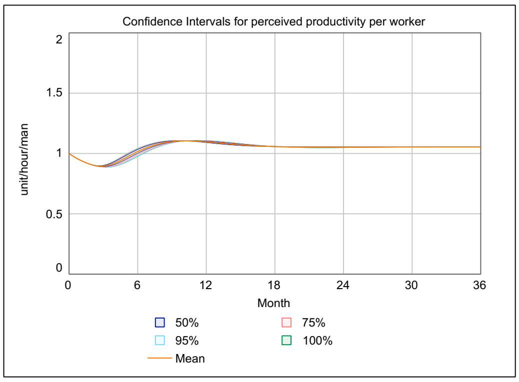
TABLE OF FIGURES

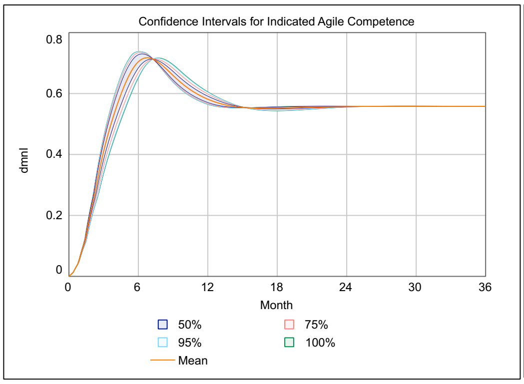
APPENDIX A – SENSITIVITY ANALYSIS

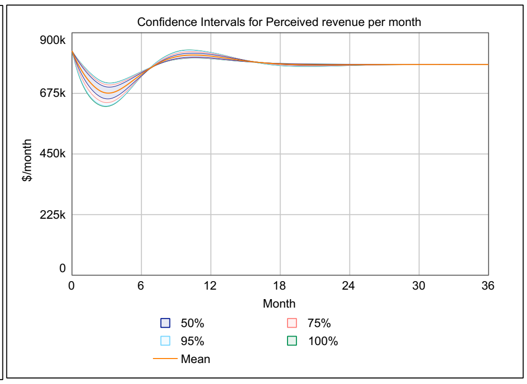
Below is the sensitivity analysis for the parameters and table functions in the model. The test was performed with a +/- 50% range of the baseline value for each parameter and 200 runs with the “Stella” sensitivity analysis tool. The further settings where Latin-Hypercube and uniform distribution. Tablefunctions where distorted and varied manually and the tested curves are depicted along the analysis below. The parameters are sorted by sector.

Sector - Calculating perceived revenue

Parameter: Time to measure revenue
Basevalue: 3 months
Tested Range: 1.5 – 4.5

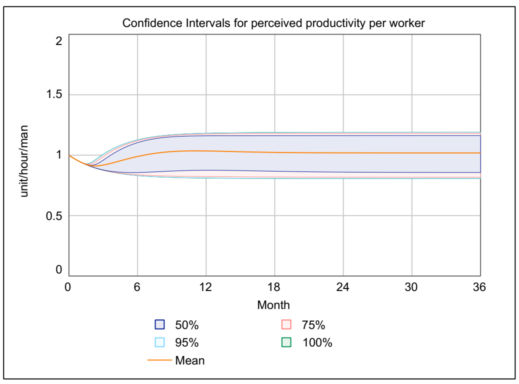


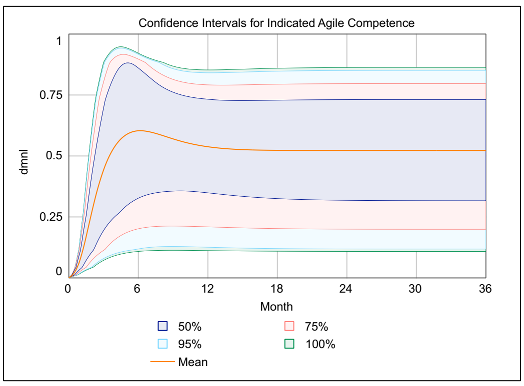


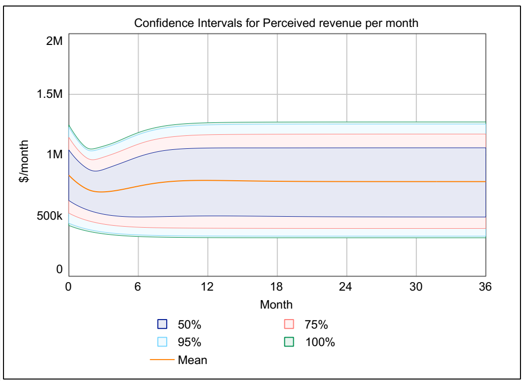


The model is moderately sensitive to this parameter. Given the same behavior pattern, the alternation in this parameter does not affect the models behavior significantly. Yet, a change in the numeric values is observable. This is to be expected, as the decision on budget allocation and thereby on the amount of training is dependent on the variation that is perceived by the management. In case of more practical application of the model a more precises value for the measuring intervals of the company should be sought and applied.

Parameter: Sales Price per Unit
Basevalue: 3.254 $/unit
Tested Range: 1.627 - 4.881

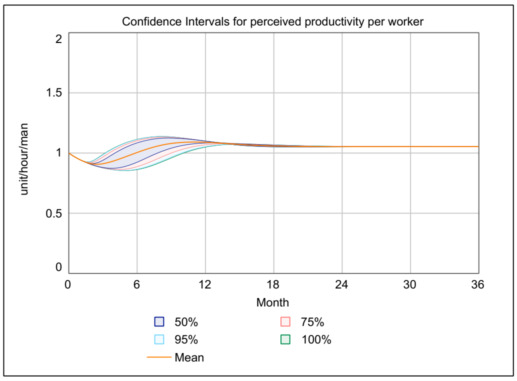


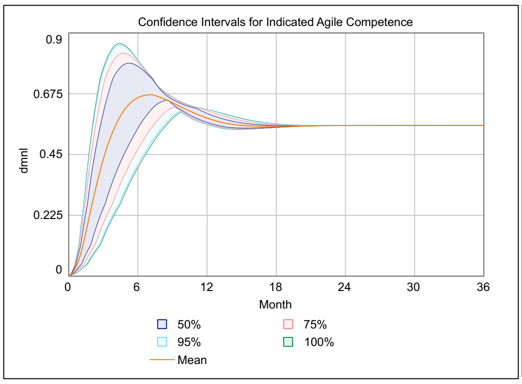


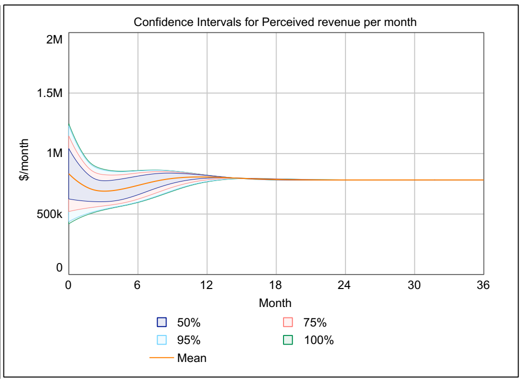


The model is sensitive to this parameter. Although model behavior is not changed in its pattern significantly in general, the model proves numerical very sensitive. This is to be expected, since the price drives the initial conditions from which the model starts and is a main driver for the generation of the budget. In varying this parameter the amount of money available for training can be influenced significantly thereby producing a wide variety in the results of indicated agile confidence and perceived revenue per month. This can be considered as a limitation since it is not clear in the outset how to determine the parameter and individual data for every usecase should be sought out to apply.

Parameter: Initial perceived revenue
Basevalue: 833 333 $/month
Tested Range: 416 666,5 – 1 249 999,5



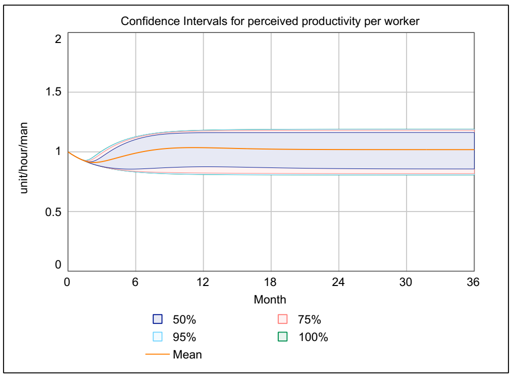


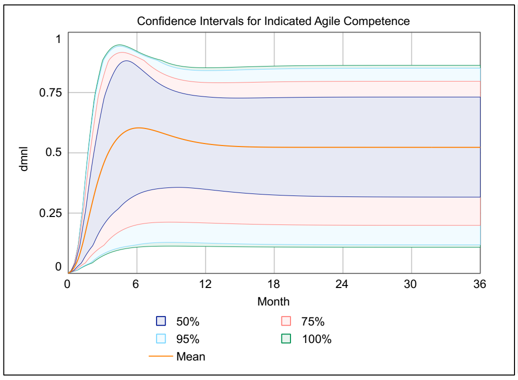


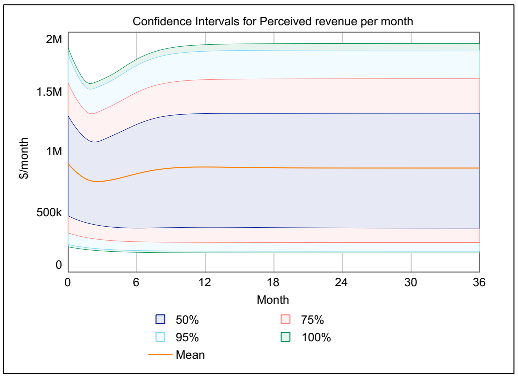
The model shows moderate sensitivity to this parameter. While the behavioral pattern stay very similar throughout the test, numerical changes can be observed. This is to be expected since the initial perceived revenue leads to main changes in the outset of the model, as can be seen in the rightest graph above. Additionally, the bigger variation in the competence building at the beginning were to be expected to, since the budget must adjust to the run with time. With higher initial revuene therefore there is more money especially in the beginning leading to a higher amount in training hours and thereby experience and indicated competence. This too, very much depends on the practical application and more precise data for this parameter should be sought when applying the model to a specific company for example.

Sector – productivity

Parameter: Number of worker
Basevalue: 40 worker
Tested Range: 20 – 60

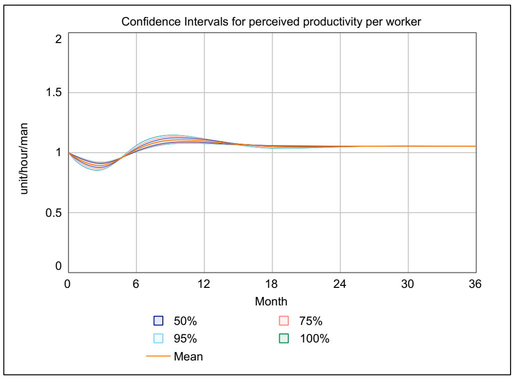


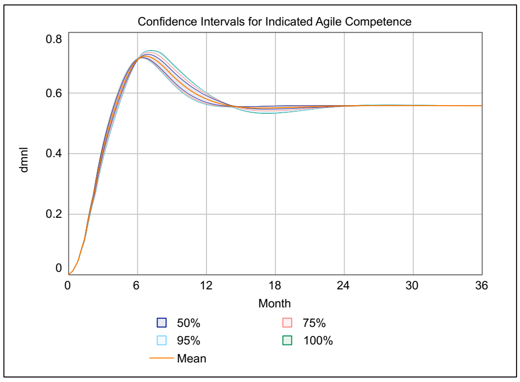


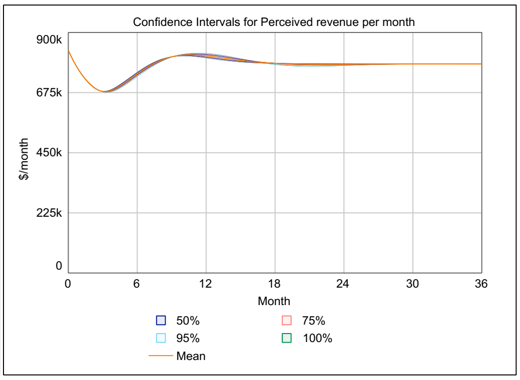


The model shows sensitivity to this parameter. Although the behavior pattern stays very similar throughout the test, numerical differences are impressive. This is to be expected, since the number of workers is crucial for the total revenue of the company and the amount of money that can be spent per worker for training. Therefore the huge variation are not surprising. The number was chose to fit the general definition of a small size company in some way, but arbitrariness of this parameter value remains unavoidable in this general model. In a more concrete application, this value should backed up with data from the company or sector it is applied to.

Parameter: Time to measure productivity
Basevalue: 3 months
Tested Range: 1.5 – 4.5

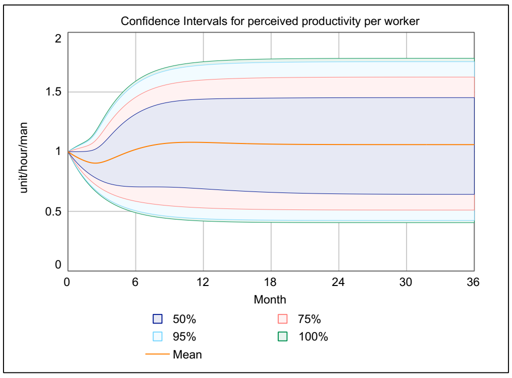


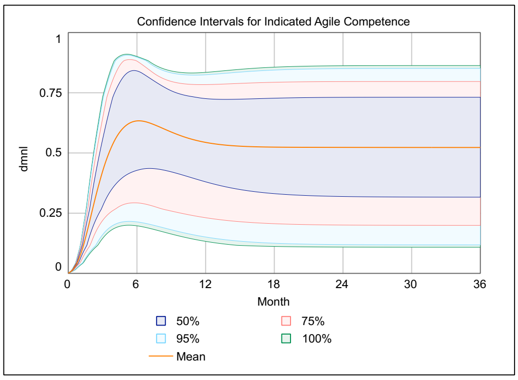


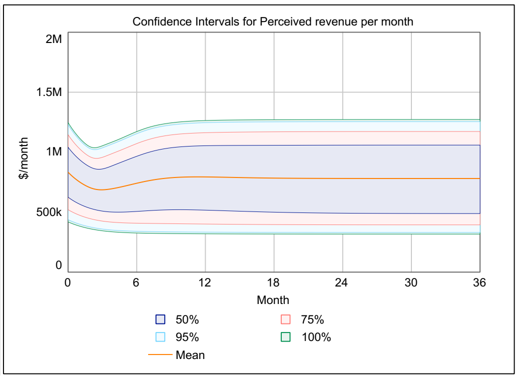


The model is almost not sensitive to this parameter. Given the same behavior pattern, the alternation in this parameter does not affect the models behavior significantly. Yet, a very small change in the numeric values is observable. This is to be expected, as the decision on budget allocation and thereby on the amount of training is dependent on the variation that is perceived by the management. In case of more practical application of the model a more precises value for the measuring intervals of the company should be sought and applied.

Parameter: Normal Productivity
Basevalue: 1 unit/hour/man
Tested Range: 0.5 – 1.5

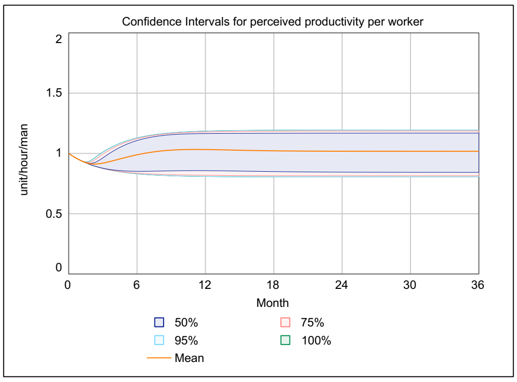


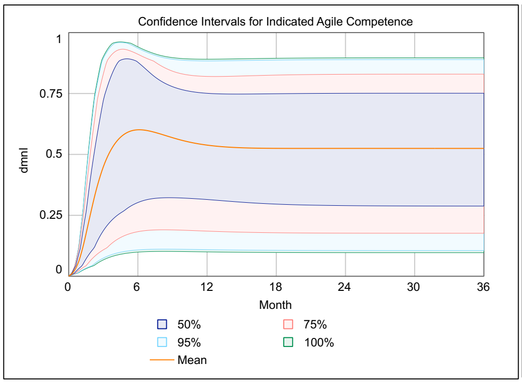


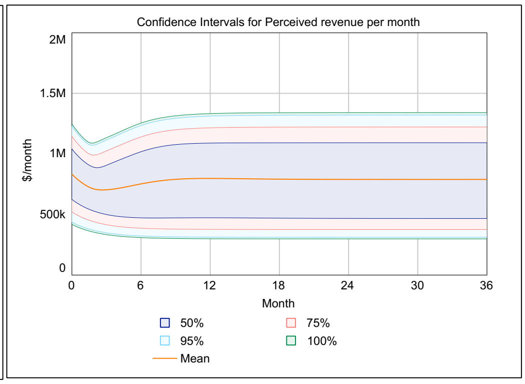


The model is sensitive to this parameter. The model behavior does vary since productivity is not coming up again in several of the runs and numerical sensitivity is quite high. This is to be expected, since the normal productivity drives a lot of the loops, especially contributing to the major loops B4, R1 and R2. Since the agile competence has an increasing/diminishing relative effect based on normal productivity the performance and revenue of the company is mainly dependent on it. With a lower normal productivity, the reinforcing loops that are responsible for the revenue to increase again are weakened, the L&D budget allocation stays low while the costs for training haven't change. Further research is need for a more accurate value.

Parameter: Standard Working hours per month
Basevalue: 160 hours/month/man
Tested Range: 80 – 240



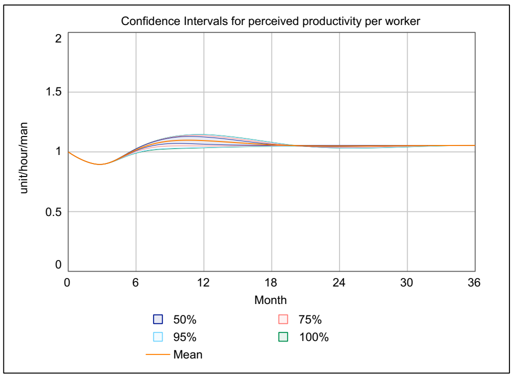


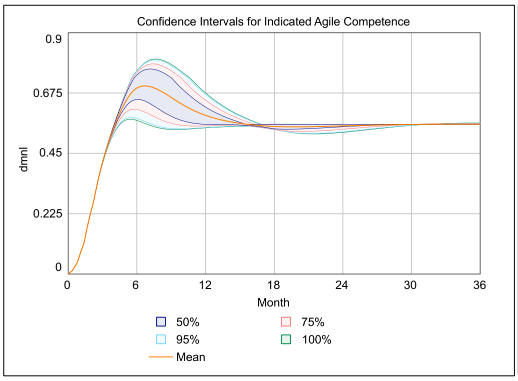


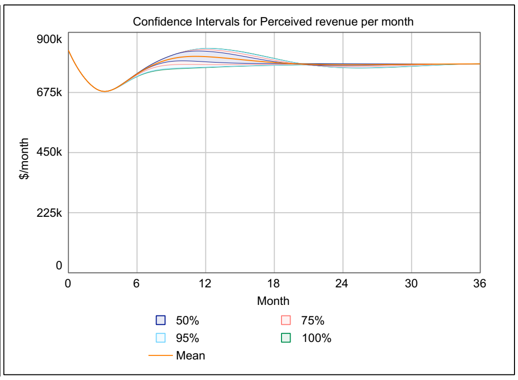
The model is sensitive to this parameter. Although behavioral pattern stay mostly very similar, except some runs where productivity is not coming up again at all, numerical changes are observable. This is to be expected, as the number of hours worked per month drives the outset revenue and the revenue calculation for each month thereby limiting how much money is available for training and weakening the R2 loop and B6 loop. Yet, as the basevalue of 160 hours corresponds to the standard working hours it remains an accurate value.

Sector – Building agile competence

Parameter: Time to measure skill progress
Basevalue: 3 months
Tested Range:1.5 – 4.5

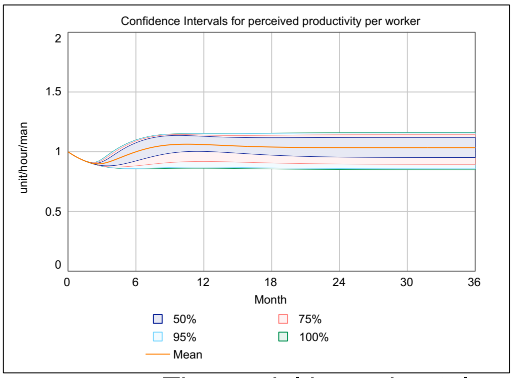


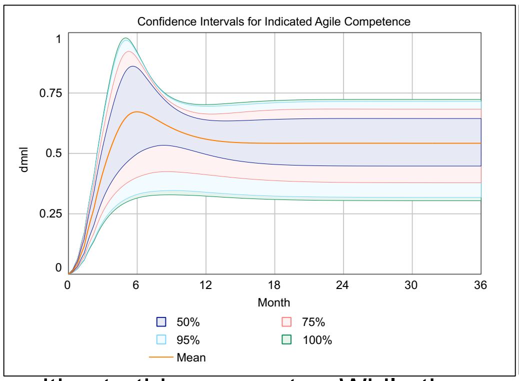


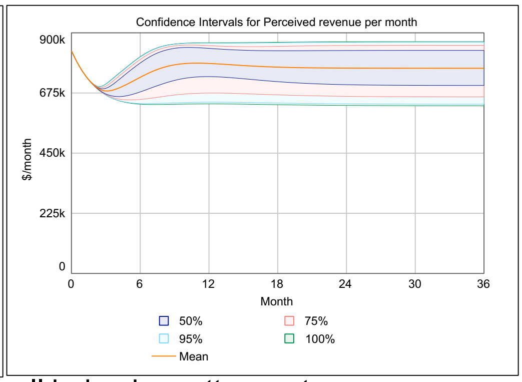


The model is moderately sensitive to this parameter. Given the same behavior pattern, the alternation in this parameter does not affect the models behavior significantly. Yet, a change in the numeric values throughout the middle-phase is observable. This is to be expected, as the decision on budget allocation and thereby on the amount of training is dependent on the variation that is perceived by the management. In case of more practical application of the model a more precises value for the measuring intervals of the company should be sought and applied.

Parameter: Normal Agile Competence
Basevalue: 0.5
Tested Range:0.25 – 0.75

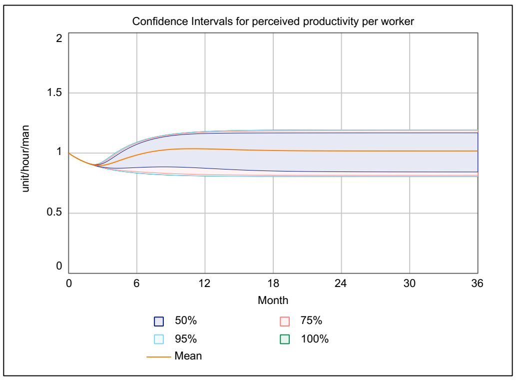


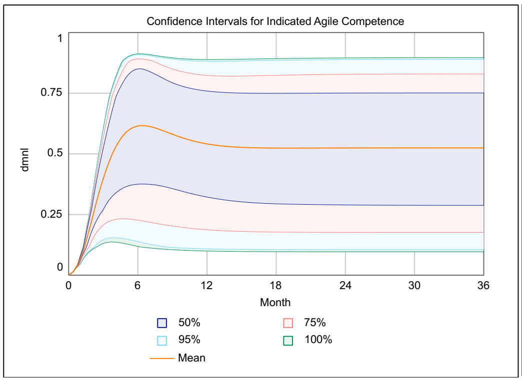


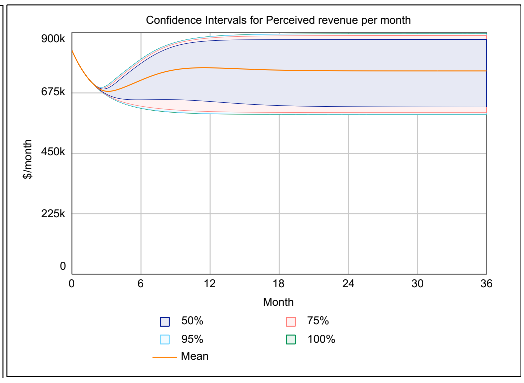


The model is moderately sensitive to this parameter. While the overall behavior patterns stay similar, numerical differences can be observed. This is to be expected since the normal agile competence what is considered to account for normal productivity. By changing the normal agile competence the indicated competence shifts up or down. This influences what is considered as “enough” agile competence to translate to normal productivity thereby influencing the R1, R2 and B4 loop. It leads to a shift or decrease (depending on the variation in the parameter) in productivity throughout the loops, e.g. the skill gap may be closed earlier leading to weaking in the B4 or the reduced productivity leads to lower revenue per month reducing the numerical values generated by R2.

Parameter: Time it takes for forgetting and unlearning
Basevalue: 3 months
Tested Range:1.5 – 4.5

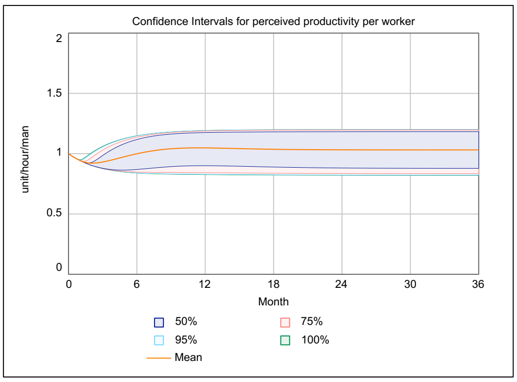


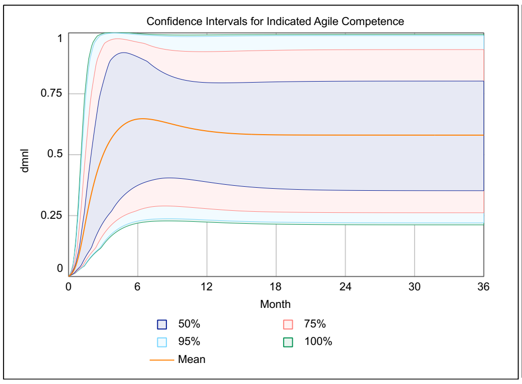


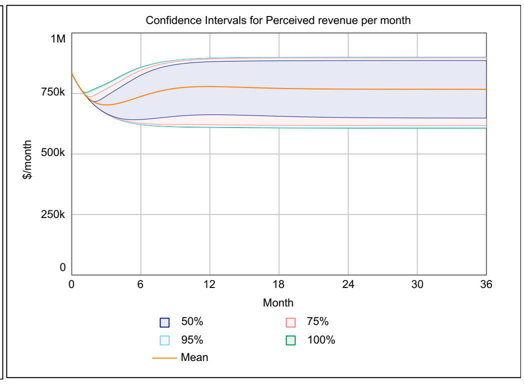


The model is numerically sensitive to this parameter, especially concerning the indicated agile competence. This is to be expected, since forgetting is draining the accumulated experience and leading to faster decline in experience hours when getting lower. At the same time the variations are not that big concerning revenue and productivity. The higher the time to forget the more time each individual have to built up experience. This translates to a higher competence, since people do not have to put in too much hours in order to maintain a certain level (You learn to learn and not to not-forget). Yet, the value is taken from the literature Morrison (2008, 1186).

Parameter: Experience per man for reaching high competence
Basevalue: 100 hours/man
Tested Range: 50 – 150







The model is sensitive to this parameter. Although model behavior remains the generally similar, except with some runs where productivity is not coming up again, the numerical value do vary under this parameter. This is to be expected, since the hours for high competence is the reference value to compare if the worker put in enough hours to perform real good, harvesting the positive effects of the agile competence. The number is assumed here and thereby definitely represents a limitation. This is because data is very subjective (how long does it take you to learn a skill on a “good enough” level?) and is depended a lot on the perception of “good enough”. Some rule of thumb for mastering a skill is 10 000 hours. Yet, employees are not to teach on that skill afterwards or need to excert it to perfection. The reasoning for this base value remain an educated estimation after all and the reasoning can be found in the documentation.

Parameter: Effect of Agile competence on Productivity

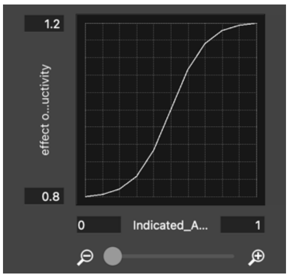


Figure 6 - Baseline Effect of Agile competence on Productivity

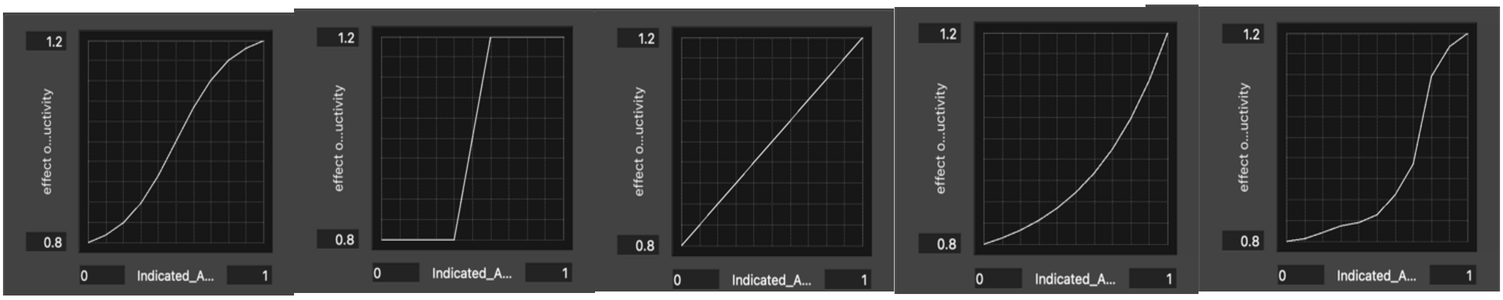
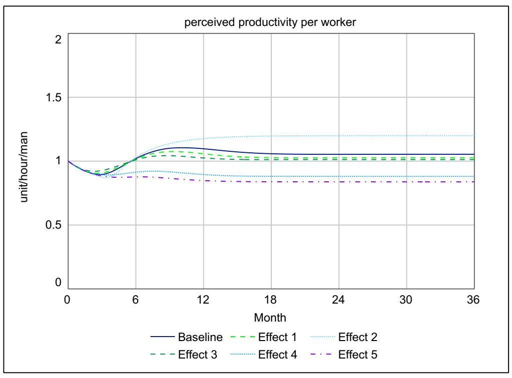
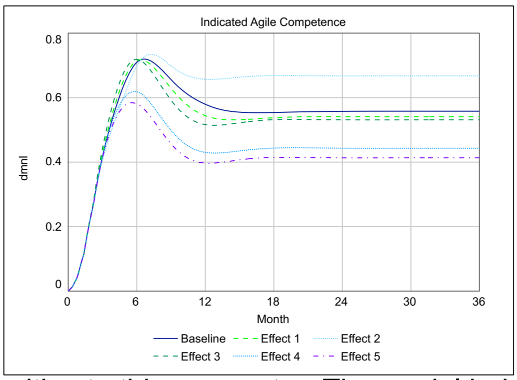
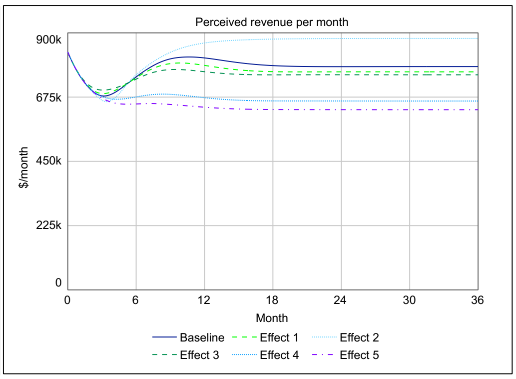


Figure 7 - Figur 4 - Variations Effect of Agile competence on Productivity corresponding to Effect 1 to 5 in the graphs







The model proves to be sensitive to this parameter. The model behavior remains the same, yet numercial changes are observable. This is to be expected. The effect translates between which level of agile competence corresponds to which “amount” of productivity. If a smaller increase around the middle is translated to a huge shift in productivity (as can be seen in effect variation 2 and the light blue dotted line with “effect 2” in the graph), then a higher productivity and more revenue can be established more easily and the level can be maintained once brought up. If it takes a long time (a lot of experience hours and therefor a high level of indicated agile competence) to translate to an increase in productivity, it is really hard for the system to build up enough hours to gain something from the learning effort. This can be seen with effect variation 5 and the graph “effect” 5 in dotted, slashed purple. Especially the upper and lower value (how much less productive you are when you have no experience in agile working and how much more productive you are, when you have a lot of experience 20%,30%) are numerically sensitive, although behavior stays still the same. This has to be considered carefully.

The effect curve can be argued for (see documentation), yet it proofs to be an assumption and limitation and more research on this translative mechanism is need to bolster up the model.

Parameter: Effect on Agile competence

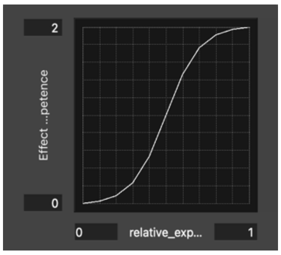


Figure 8 - Baseline Effect on agile competence

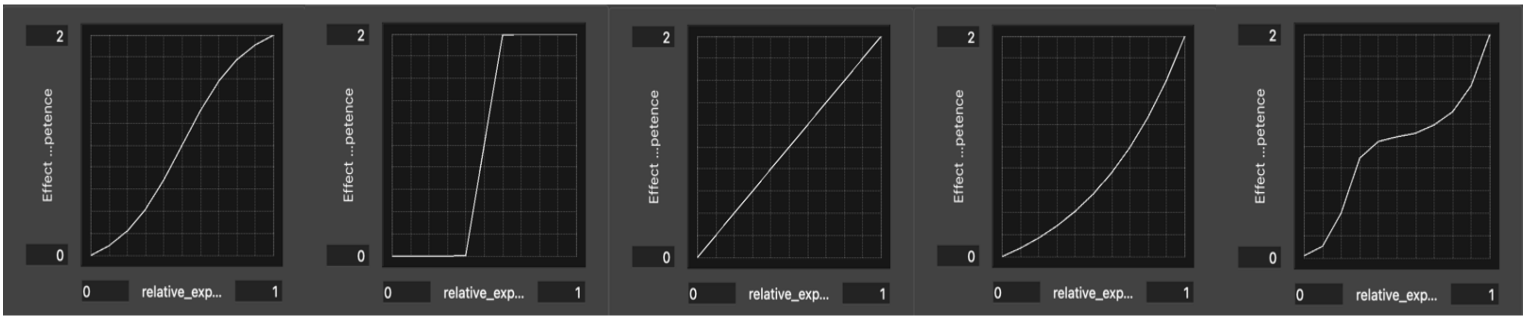
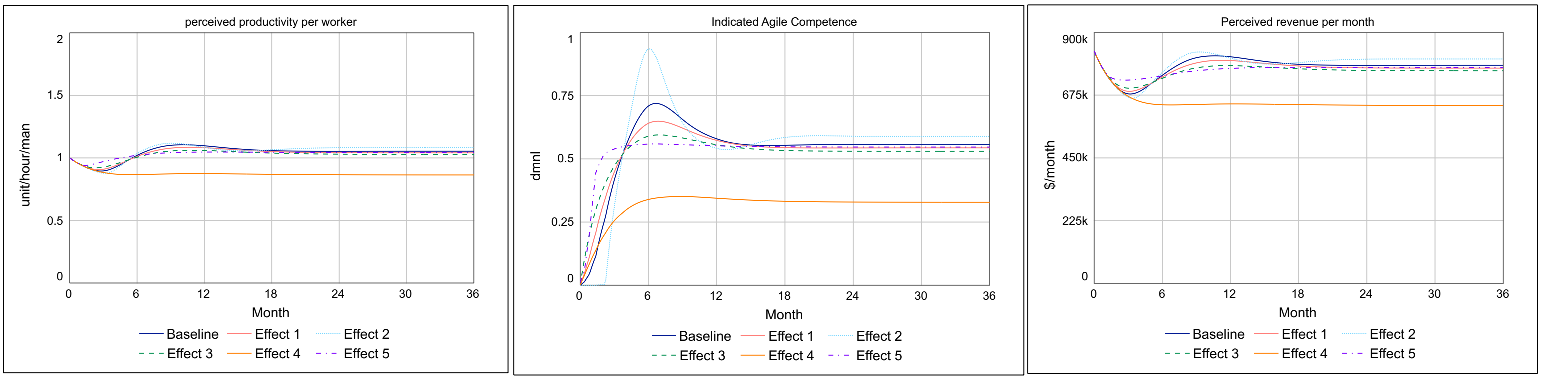


Figure 9 - Variations for effect on agile competence corresponding to Effect 1 to 5 in the graphs

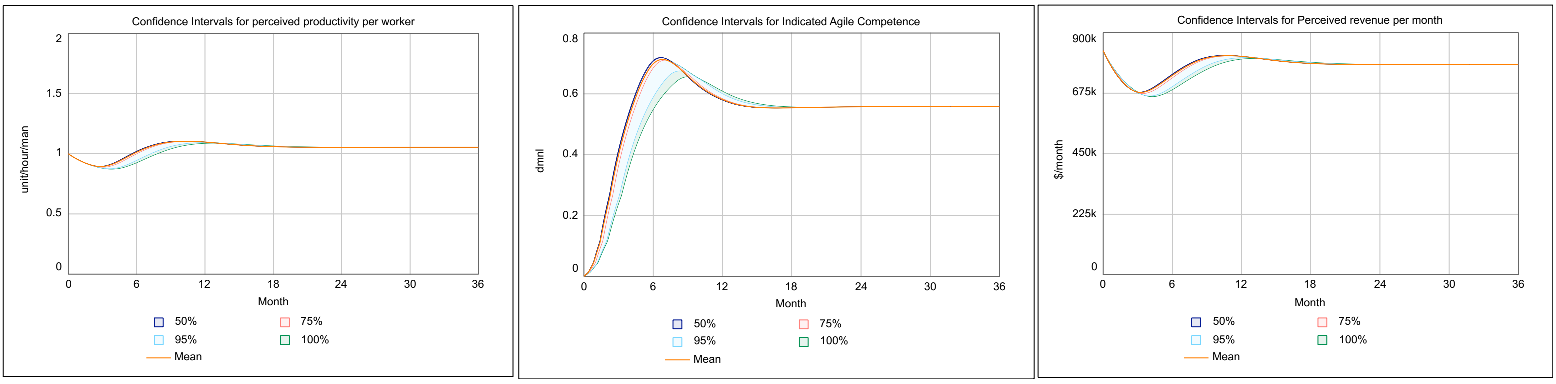


The model proves to be numerical but only moderately behavioral sensitive to this parameter. This is to be expected, since the effect shows how the relative built up experience translates to agile competence and by that drives indicated competence, which in turn has a huge impact on the major R1, R2 and B4 loops. One can see that with the exponential growth function in effect variation 4, the competence is built up so slow and experience hours very tediously built up to higher competence, that indicated agile competence and revenue per month don't come up but the equilibrium between training hours and forgetting hours is sought and the whole training hasn't had that big of an effect.

This relationship too, is assumed and argued for, yet more research for a more accurate or robust description of this relationship is necessary in order to make the model more robust.

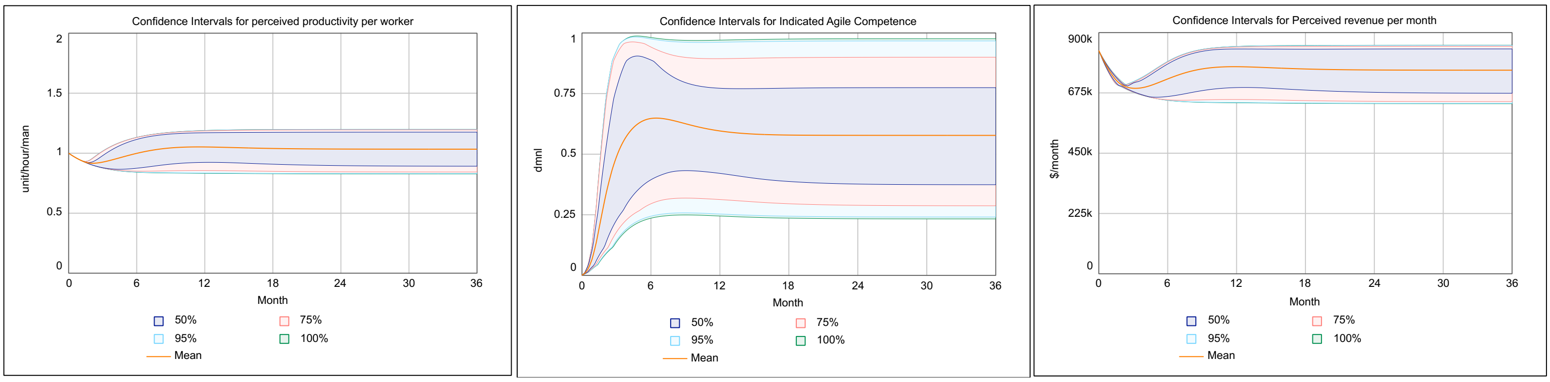
Sector – Allocating ressources for competence building

Parameter: Max hours of training per worker per month
Basevalue: 40 hours/man
Tested Range:20 – 60



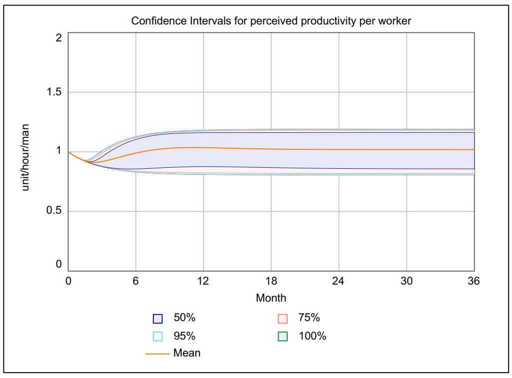
The model shows very low sensitivity to the parameter. No behavioral and only insignificant numerical changes are seen here.

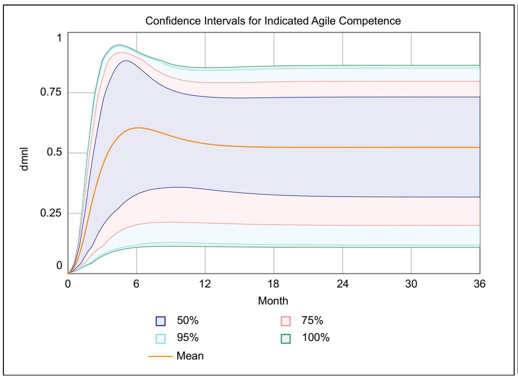
Parameter: Average Cost of L&D per worker per month
Basevalue: 106$/man/month
Tested Range: 53 - 159

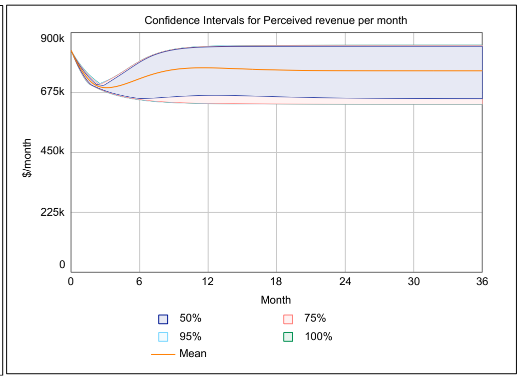


The model is sensitive to this parameter. Although behavior pattern remain quite similar the model shows numerical changes in varying this parameter. Especially in the extreme conditions behavior can change so that productivity is not coming up again, since not enough competence is build up. This is expected since the cost of Learning and Development per worker drives the amount of hours per worker the company can effort to buy with their budget. This leads to a higher or lower number of hours bought thereby having a big impact on the amount of training and building up competence. The value reflects a statistical average and is arguably fit to be kept, yet a more precise number is need in further research.

Parameter: Average hours per worker on L&D per month
Basevalue: 2.92 hour/man/worker
Tested Range: 1.46 – 4.38

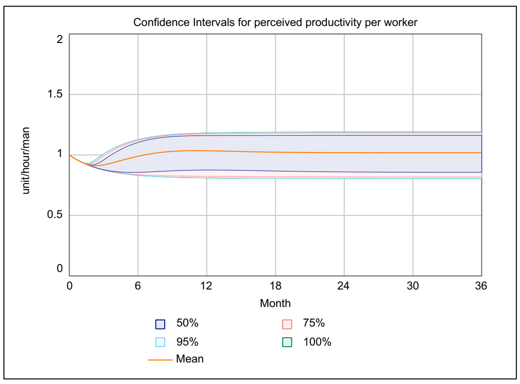


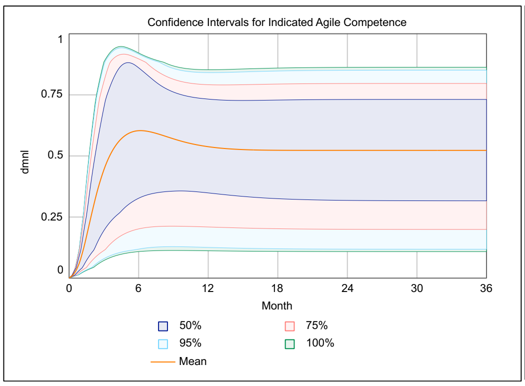


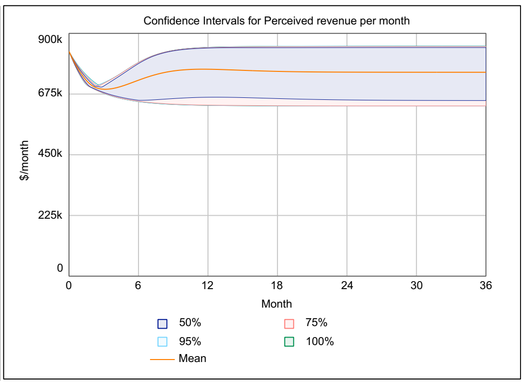


The model is moderately sensitive to this parameter. In the extreme conditions the model behavior can shift in the sense that productivity does not come up again, since there are to less hours affordable to the company. The numerical values change by varying the parameter. This is to be expected, since the average hours are used to calculate the price for L&D per hour per worker and by that has a big impact on how much hours of training the company can afford. If the average hours are high, given the average costs, the cost per hour is small so the company can afford several more, having more training a faster buildup of experience and by that also a faster relapse of the productivity and the revenue to a higher level. If average hours are small the costs are high leading to the opposite mechanism. The average number is based on a statistical survey and by that seems to be good enough for this abstract model. More research and more precise application to the specific company is need in further research tough.

Parameter: Normal fraction of budget for L&D
Basevalue: 0.035 dmnl
Tested Range: 0.0175 – 0.0525

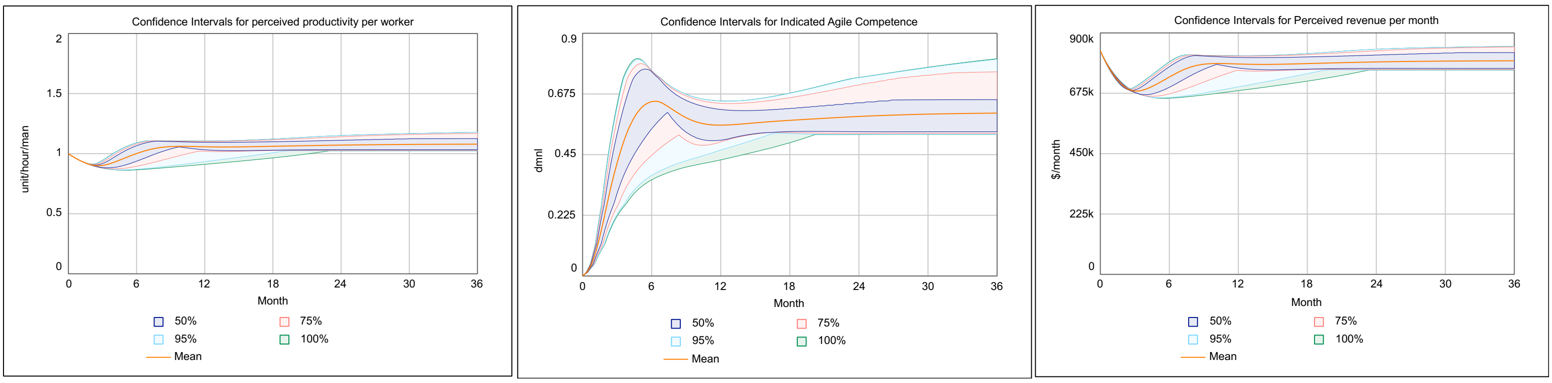






The model is sensitive to this parameter. In the lower extreme conditions the model can shift towards a behavior where productivity does not come up again due to too less training. This is consistent with the model and expectable since the normal fraction for L&D is the main driver for calculating the amount of revenue that is used for L&D. If this percentage is very low, the company does not spend money on the new training, obviously leading to almost no training, no experience accumulation thereby (in the extreme) of almost nullifying the B4 loop and weaking the R1 and R2 so strong numerically, that nothing really can be build up. A more accurate number for this parameter is definitely needed in further research, since this is both a limitation and a leverage point here. Limitation, since this parameter can easily influence a lot of the models numeric and in some ranges behavioral results, a leverage point since the company could decide on spending more thereby intensifying there training and having long term positive effects.

Parameter: Weight on Skillbuilding (and respectively productivity)
Basevalue: 0.5 dmnl
Tested Range: 0.25 – 0.75



The model is sensitive to the parameter. The behavioral patterns as well as the numerical values do change. This is to be expected since the weight controls the power of R1 and B4. Especially with an empowered B4 the model shows oscillatory behavior. This is because with weight = 1 the balancing loop is so strong that it dominated the system and create oscillations through the information delay. This leads the company to always react to the too late perceived change in skill. Interestingly, for the behavior to show more desired output in the long run, the company should reduce the weight on skill building. This is because than the skill is build up steadily and sustainably instead of a fast increase in skill but then also a

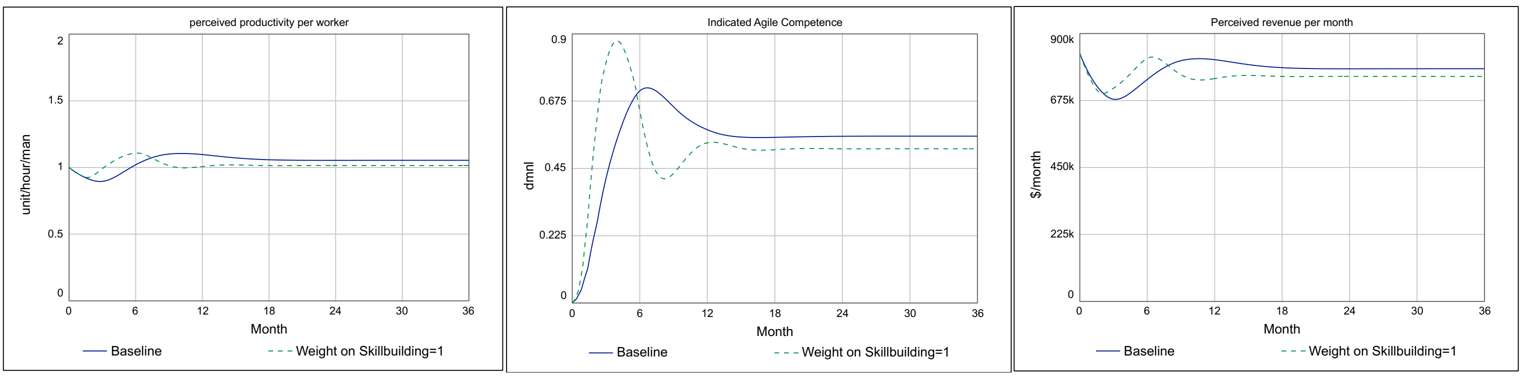


Figure 10 - Model run for Weight on Skillbuilding = 1

fast decline (since forgetting is driven by the amount of the experience stock). The values of this parameter should be researched to better fit specific cases and to accurately represent the decision logic of the company. This is still not to be considered only limitation here, but too a leverage point the company can use.

Parameter: Effect of Relative Productivity on Budget

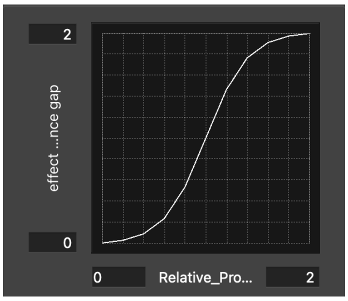


Figure 11 - Baseline Effect Relative Productivity

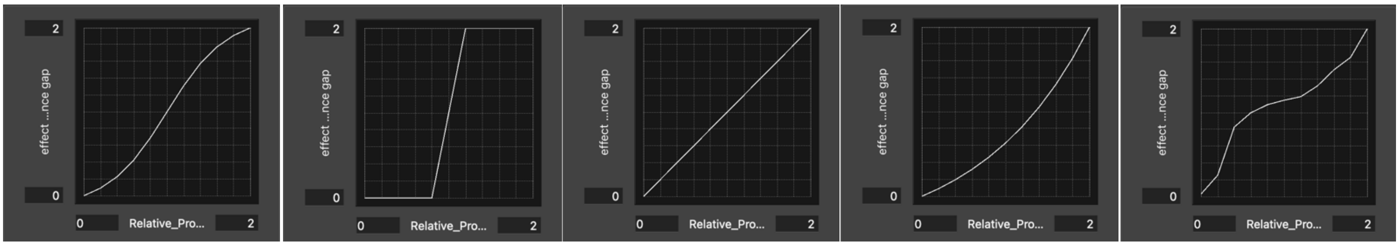
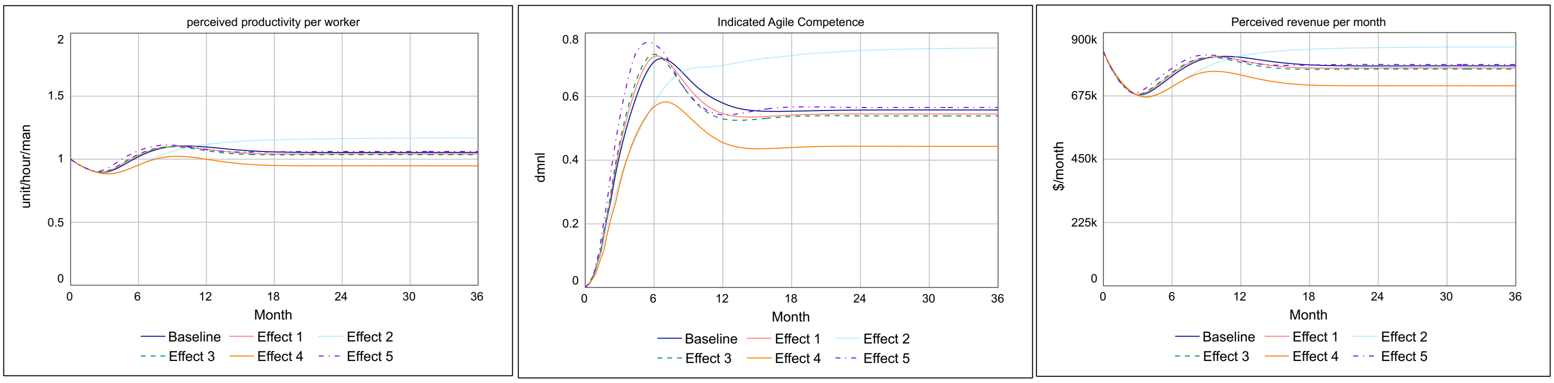


Figure 12 - Variations corresponding to Effect 1 to 5 in the graphs



The model is only moderately sensitive to this effect table, since model behavior stays very similar and numerical values do not change too much. However, this relationship also represents a value judgement of the company and thereby should be research to fit each individual case more accurately.

Parameter: Effect of Skill Gap on Budget

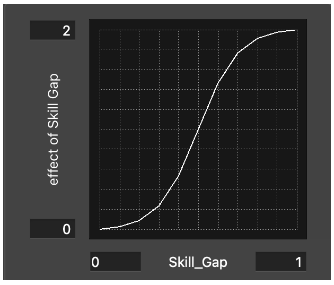


Figure 13 - Baseline Effect Skill Gap

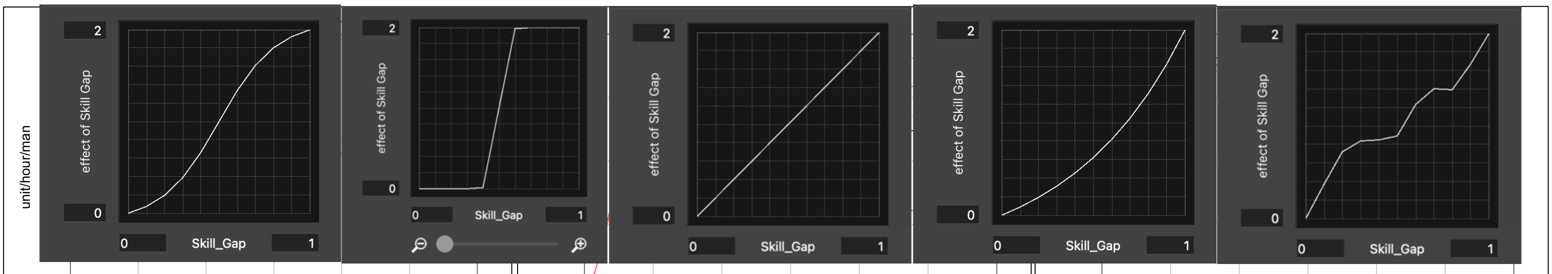


Figure 14 - Variation of Effect Skill Gap corresponding to Effect 1 to 5 in the graphs

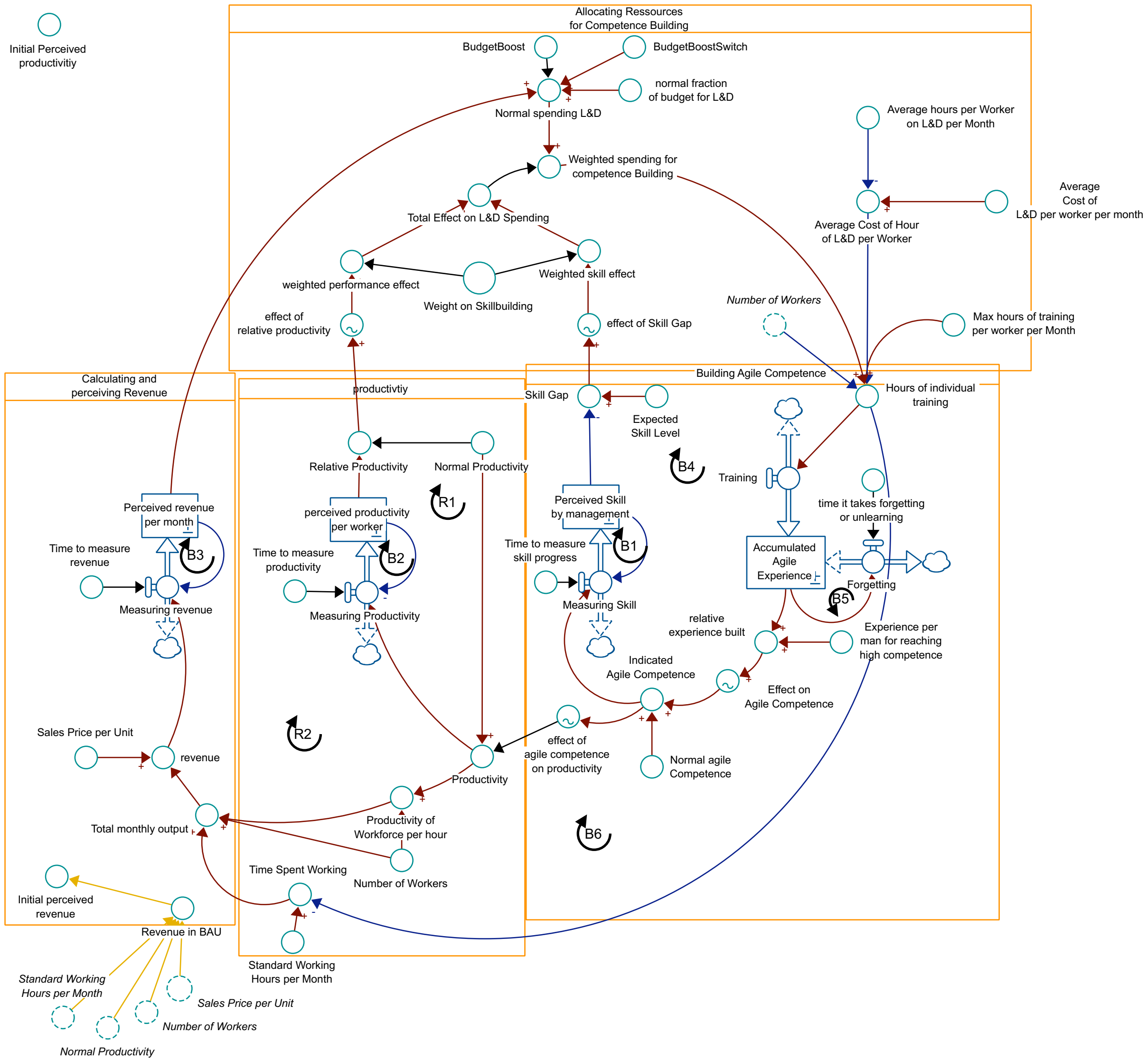
Baseline Effect 1 Effect 2
Effect 3 Effect 4 Effect 5

The model is sensitive to this effect table, since model behavior and numerical values do vary. This shows that the effect the skill gap has to the allocation of budget is both, a limitation of the model and a leverage point within the model for the company. This relationship also represents a value judgement of the company and thereby should be research to fit each individual case more accurately.

At the beginning of the simulation the skill gap is most naturally the biggest (no training has happened so far) and it is crucial that this has an early impact on the allocation (as can be seen for example in the linear variation effect 3). Vice versa, as can be seen with effect 4 exponential relationship, as effect of the skill gap reduces increasingly (one can figure to go from right to the left of the effect graph as the skill gap closes from one to 0) even with a high gap, the company does not allocate as much revenue for further training. This leads to a stagnation in the building of experience hours with translate to a lower coming back of producitivty and revenue. Further down in time then, there is not enough money left to boost up training enough again, although the skillgap may then be bigger again.

Overall, this effect variable proofs to be in need of further research, in order to back up the model and this relationship.

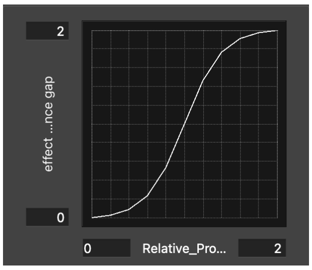
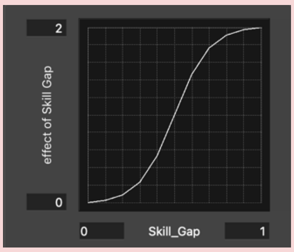
APPENDIX B – MODEL STOCK-FLOW - DIAGRAM



APPENDIX C – MODEL DOCUMENTATION

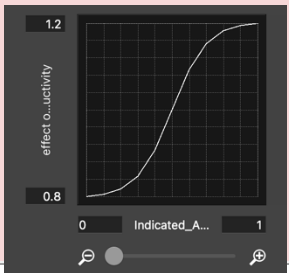
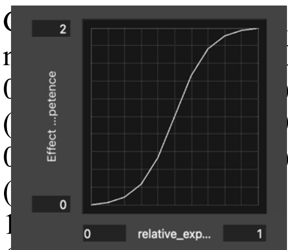
This documentation uses the minimum requirements of model documentation put forward by Rahmandad and Sterman (2012).

	Equation	Units	Documentation
Sector Allocating Resources for competence building			
Average_Cost_of_Hour_of_L&D_per_Worker	Average_Cost_of_L&D_per_worker_per_month/ Average_hours_per_Worker_on_L&D_per_Month	$/hour	Equation: Average_Cost_of_L&D_per_worker_per_month/ Average_hours_per_Worker_on_L&D_per_Month Unit: $/hour Cost of one hour of L&D per worker based on the asumption of average hours for L&D and an average cost of L&D per worker.
Average_Cost_of_L&D_per_worker_per_month	1270/12	$/man/month	Represent the amount of money a company spend on average for L&D. It is measured in the USA and can only function as a educated estimation. More data is surely needed here. Source is a statistacal analysis by Statista (2021a). The survey does not include a description on what this amount is made off. As an assumption though it is taken, that the amount of money a company a spends on a worker for L&D covers both, the indirect and direct costs (direct costs for the training agency and indirect cost by paying their employees the time it takes to train). Especially if one wants to amend the model with representing the training, trainer and consultant agency structure, this has to be considered!
Average_hours_per_Worker_on_L&D_per_Month	35/12	hour/man/month	Resource: Statista (2021b) The amount of hours each worker spends per month for L&D (measured in the USA in 2020). This value is in US$ and will be used without accounting for the exchange rate to EUR.
BudgetBoostSwitch	0	dmnl	Switch for the Budget Boost Policy that increases the normal fraction spent for L&D. Policy can be activated by switching the switch to 1.
BudgetBoost	0.01	dmnl	Represents the Boost on the normal fraction spent on L&D that is added when the policy is activated by the switch. Arbitray and assumed number but variable.
effect_of_relative_productivity	GRAPH(Relative_Productivity) Points: (0.000,	dmnl	This represents the effect from the relative performance towards the budget allocation for

	0.000), (0.200, 0.02526), (0.400, 0.08682), (0.600, 0.2331), (0.800, 0.5352), (1.000, 1.000), (1.200, 1.465), (1.400, 1.767), (1.600, 1.913), (1.800, 1.975), (2.000, 2.000) 		more or less training. The relative performance is depended on the perceived productivity by the management and the normal productivity. In a scenario where the relative productivity is equal to the normal productivity, the effect give 1 back indicating that, the normal amount of L&D spending can be used for training. In scenarios where the relative productivity is bigger (higher) than 1, meaning that employees are already pretty productive, the effect allows that the budget will be streched out more and more, yet with a diminishing effect (S shape), since the company can effort more training In scenarios where the relative productivity is smaller than 1, meaning the employees are less productive then hoped leading to less revenue per month the company reduces the amount of training in order to have people work more.
effect_of_Skill_Gap	GRAPH(Skill_Gap) Points: (0.000, 0.000), (0.100, 0.02526), (0.200, 0.08682), (0.300, 0.2331), (0.400, 0.5352), (0.500, 1.000), (0.600, 1.465), (0.700, 1.767), (0.800, 1.913), (0.900, 1.975), (1.000, 2.000) 	dmnl	This represents the effect from the skill gap towards the budget allocation for more or less training. The skillgap is depended on the perceived skill by the management and the expected skill level from the management. In a scenario where the skill gap is present but not that strong (indicated with 0.5) the normal amount of L&D spending will be used, the effect give back 1. In scenarios where the skill gap is bigger (higher) than 0.5, meaning training is not going so well, people do not develop the skill fast enough etc., the budget will be streched out more and more, yet with a diminishing effect (S shape), since more training is essential to counter the deficit but wont be reasonable endlessly. In scenarios where the skill gap is norrower, smaller than 0.5, meaning the training is going well, the company considers to relax a little on the training in order to have more time to spent working. Therefor the budget for the training gets shortend.
Max_hours_of_training_per_worker_per_Month	40	hour/man/month	Represents the limit on hours each worker spends per month on training. This number is assumptive and represents a fourth of the usual hours each worker has in a work-month. When one thinks about it this assumption

			may be quite high if acted out over a long period of time and it seems arguably extreme but not completely unrealistic that a company allocates one week of training for an employee per month.
normal_fraction_of_budget_for_L&D	0.035	dmnl	Data for the percentage of revenue spent for L&D is hard to come by. This fraction is an rough proxy, though more data is necessary. While one webpage claims that companies spent 2-2.5% of their revenue on L&D another (F.learning Studios 2022) webpage depicts a statistic on Research and Development Budget allocations with an average total of 4% (Sather, 2021), yet another recommends an allocation between 1 - 5 % (Sucess Coaching n.d.; American Express 2022). Neither of these source may account directly to scientific standards, but the hint at and educated guess for the fraction somewhere in the middle. Thats why a percentage of 3.5% was used. Nevertheless this remains an assumption, that needs to backed up by further research and more data.
Normal_spending_L&D	normal_fraction_of_budget_for_L&D*Perceived_revenue_per_month*(1-BudgetBoostSwitch) + BudgetBoostSwitch*((normal_fraction_of_budget_for_L&D+BudgetBoost)*Perceived_revenue_per_month)	$/month	Equation: normal_fraction_of_budget_for_L&D*Perceived_revenue_per_month Unit: $/month Calculates a "normal" L(earning) & D(evelopment) spending. This is based on a normal fraction a company uses to calculate their average budget for L&D. This is based on the revenue that is at their disposal, and their decision on how much of that revenue will be used for L&D. The higher the normal fraction of budget for L&D the higher the average spending. The higher the perceived revenue per month, the higher the average spending.
Total_Effect_on_L&D_Spending	weighted_performance_effect+Weighted_skill_effect	dmnl	This combines both weighted effects in order to find a budget allocation for L&D spending. This variable, due to its inputs, will range between 0 and 2, so in the extrem conditions (with a equal weight and a skillgap of 1 and a relative productivity of 2) the L&D budget will be double as high as normal, while if the skill is built up, and productivity is very low (an in that combination unrealistic scenario) the L&D spending would be 0.
Weight_on_Skillbuilding	0.5	dmnl	This is the weight the company puts on skillbuilding to weigh the effects of the deficits. The remaining decimal to 1 (1-Weight on Skillbuilding) is the weight for the productivity

			effect. The variable has limit range between 0 and 1 (for percentage). This represents a dual choice where the company puts weight on either of those, and is by that, of course a simplification, due to the model boundary. In the baseline scenario the company is putting equal weight (0.5) on both sides.
weighted_performance_effect	(1-Weight_on_Skillbuilding)*effect_of_relative_productivity	dmnl	This represents the effect of the relative performance on the budget allocation weighted by the management. In the baseline this is 0.5 to indicate, that productivity losses will be tried to counter act with the same weight as skill deficits. This is decision point and an individual weight should be found for the company.
Weighted_skill_effect	effect_of_Skill_Gap*Weight_on_Skillbuilding	dmnl	This represents the effect of the skillgap on the budget allocation weighted by the management. In the baseline this is 0.5 to indicate, that skill deficits will be tried to counter act with the same weight as productivity losses. This is a decision point and an individual weight should be found for the company.
Weighted_spending_for_competence_Building	Normal_spending_L&D*Total_Effect_on_L&D_Spending	$/month	Equation: Average_spending_L&D*Total_Effect_on_L&D_Spending Unit: $/month Calculates the budget that is used to buy training. This is the total budget the company allocates for learning and Development for the next month. It is based on the average spending of the company that is now manipulated by the weighted effect of the skillgap and productivity losses. This represents a decision mechanism that indicates that the change in skill and productivity has influence on the allocation of budget for training. Higher the combinated effect, the higher the budget for L&D. Since the effect ranges from 0 to 2, the maximum budget for L&D can be twice as the normal spending of the company, the minimum being 0.
Sector Accumulating agile competence			
Accumulated_Agile_Experience(t)	Accumulated_Agile_Experience(t - dt) + (Training - Forgetting) * dt	hour/man	Stock. Inflow: Training Outflow: Forgetting Initial: 0 (since this is the competence that should be build up) Accumulated Hours of Experience with agile training. As the the hours accumulate this

			translates to more competence. The Stock increases with the inflow of training and gets drained by the forgetting flow. This structure is adapted and modified from the paper from Morrison (2008).
effect_of_agile_competence_on_productivity	GRAPH(Indicated_Agile_Competence) Points: (0.000, 0.8000), (0.100, 0.8051), (0.200, 0.8174), (0.300, 0.8466), (0.400, 0.9070), (0.500, 1.0000), (0.600, 1.0930), (0.700, 1.1530), (0.800, 1.1830), (0.900, 1.1950), (1.000, 1.2000) 	dmnl	The effect the agile competence has on productivity. The structure is supported by logical thinking and Morrison (2008, 1184). The paper suggests that after a process change a loss in productivity is observed before an accumulate experience leads to an increase in productivity again Morrison (2008, 1184). If agile competence is very low, the effect is leading to a reduction in productivity. When starting and Agile competence is around 0 this means that productivity is at 80% (0.8), since the processes and methods are different, people need to adapt to them, learn them and this consumes time and hindering full productivity. Note, that the amount of productivity drop (20%) (and increase) is an assumed value. Yet with increasing competence, productivity comes back. At 0.5 Agile Competence, the normal productivity level is gained again. After that, the change pays off: The higher the agile competence the more productive the worker will be until at a competence of one the productivity peaks at 1.2. This is to indicate, that agile working leads to being more "productive". This is difficult to translate, because not every agile method is supposed to facilitate more productiveness in the sense of more units with the same effort / same units with less effort. Some competencies are focused on maximizing the value of the product in terms of expectations of stakeholders and a method of working that better depicts this satisfaction. In anyways though, this can be proxied with a higher productivity.
Effect_on_Agile_Competence	[illegible]  (0.800, 1.913), (0.900, 1.975), (1.000, 2.000)	dmnl	This effect translates the experience a employee has with agile competence via training or guided work into agile competence. If an employee gathers 50% relative experience (0.5) this translates to a indicated effect of one on the normal agil competence. This is to capture that a certain level of experience is good enough to already work smoothly with the new framework, while at the same time leaving room for improvement in experience and competence. The S-Shape is chosen to capture one intuition and one learning effect: 1. The S-Shape captures the intuition how learning

			builds up. It takes some time, some hours to get started with the material and getting familiar with the concept. In that beginning, below 0.5 and close to zero, the gain in additional hours of experience has not that much of an impact but impact is increasing increasingly as the learner builds up momentum. After the tippingpoint at 0.5/1 , the it takes more and more hours to add up more competence, meaning that once a solid base is built up to get even higher in competence one must put in the hours. This is accounted for by the diminishing returns effect of the S-shape. 2. The S-shape function captures in someway the learning concept that the more one has learned the better one can learn. The hours spent with the competence has, to some level, an reinforcing effect on the learning outcome. Yet once a significant amount is reached (0.5) this effect diminishes, as described above.
Expected_Skill_Level	1	dmnl	Represents the perception of how the skill should develope as wished by the management. This is corresponds to one in this scenario, since management tries to achieve the new skill. Yet, theoretically this could vary as management could also be satisfied with a lower percentage of the skill.
Experience_per_man_for_reaching_high_competence	100	hour/man	This variable represents the amount of hours that are necessary to reach a high competence in agile working. This is unavoidably very assumptive, but the number is based on an educated reasonable guess from courses throughout some skillbuilding platform. Courses in agile project management or Scrum Master certification vary but keep in a range from 20 to 30 hours for the beginners level (Coursera 2022b; 2022a; Scrum Alliance n.d.). Considering that a high compentence is more than just the beginner level, the necessary hours of two courses where considered and multiplied by two, since the sole learning hours should be accompanied by around the same amount of guided training with a coach. This considerations results in two packages of 25 hours on average combined with the same amount of practical implementation time, which results in 100 hours per man. This assumption therefore is grounded in some reference, but more data is surely necessary. It was considered here, that employees need not to be able to teach the skill later on (which would require a lot more practice hours) but to be just very competent in using it in their daily work.

Forgetting	Accumulated_Agile_Experience/time_it_takes_forgetting_or_unlearning	hour/month/man	Represents the outflow of knowledge. This implies there is a continous need for learning and refreshing the skill. The forgetting structure corresponds to the literature and can be seen as both, the organizational forgetting via new hires and collective knowledge depreciation and the individual forgetting (Morrison 2008; Anderson and Lewis 2014; Argote 2013; N.P. Repenning and Sterman 2002)
Hours_of_individual_training	MIN((Weighted_spending_for_competence_Building/Number_of_Workers)/Average_Cost_of_Hour_of_L&D_per_Worker, Max_hours_of_training_per_worker_per_Month)	hour/month/man	Equation: MIN((Weighted_spending_for_competence_Building/Number_of_Workers)/Average_Cost_of_Hour_of_L&D_per_Worker, Max_hours_of_training_per_worker_per_Month) Unit: hour/man/month This equation calculates the amount of training each worker is allocated given 1) The amount of revenue the company assigns for investing in L&D 2) The cost for an hour of training on average given the data in the converters leading to that equation 3) the number of employees that are employed with the company. The result is the number of hours each worker gets training given the budget. The MIN function ensures that even if revenue and the L&D spending accordingly maybe very high, the amount of training per man in one month does not go beyond a certain maximum of hours each worker can spend for training. This is to ensure that the number of hours for training is kept realistic between zero and the maximum hours of training per month (i.e. the company realistically would not allow for the workers to train all their hours of the month)
Indicated_Agile_Competence	Normal_agile_Competence*Effect_on_Agile_Competence	dmnl	Equation: Normal_agile_Competence*Effect_on_Agile_Competence Unit: Dmnl Indicated current competence level measured on the hours accumulated, weighed with the effect and in relation to a normal level of agile competence which represents the competence with its effect on productivity
Measuring_Skill	(Indicated_Agile_Competence-Perceived_Skill_by_man	Per Month	Flow. Equation: (Indicated_Agile_Competence-Perceived_Skill_by_management)/Time_to_measure_skill_progress

	agement)/Time_to_measure_skill_progress		Unit: 1/month Represents addition to the stock of the perceived skill of the employees recognized by the management. This is an information delay formulation. This structure captures the fact, that management has to measure the amount of skill in order to take it into account for reallocating budget.
Normal_agile_Competence	0.5	dmnl	Represents an normal agile Competence which is enough to account for the "normal" productivity of 1. This is an estimated and assumed value.
Perceived_Skill_by_management(t)	Perceived_Skill_by_management(t - dt) + (Measuring_Skill) * dt	dmnl	Stock - Information Delay. Initial: 0 (since this represents the managements perspective on the skill that is neeeded to build up) This represents the skill level the management recognizes for its employees. It is delayed because of measurement means that need to take place in order to get a picture of the current skill - situation. This structure is captured by an information delay and updated through the measurement flow.
relative_experience_built	Accumulated_Agile_Experience/Experience_per_man_for_reaching_high_competence	dmnl	Equation: Accumulated_Agile_Experience/Hours_per_man_for_reaching_high_competence Unit: Dimensionless Represents the relative competence the worker has already built up so far. For this, the accumulated hours with training is compared to the amount of hours needed to gain a high competence. 0 meaning no competence is built up at all and 1 meaning that the necessary amount of hours is accumulated therefor accounting that the worker has built up 100% of the hours ecessary to reach high competence. This concept is arguably tricky since the value could go above 1 theoretically. This means that more than 100% high competence is built up, which sounds unrealistic at first. Yet in comparision to some arbitrary value and threshold of high competence this makes sense. One can of course be more advanced than "high competence" and therefor go beyond 1 (achieving mastery instead). This is to be neglected in the model though, since this structure represents that with a sufficient amount of competence the positive effects on productivity will be achieved.

Skill_Gap	Expected_Skill_Level-Perceived_Skill_by_management	dmnl	The gap between the desired level of skill and the perceived on. Has impact on the budget for competence building
time_it_takes_forgetting_or_unlearning	3	months	Time to forget what was learned by learning by doing. Estimate stems from Morrison (2008), but more and detailed data is needed to determine this value.
Time_to_measure_skill_progress	3	month	Time it takes for the company to recognize the progress their employees have made in terms of the skill. The value is an assumption but is based on the premise that the management assess the stats of the company every quarter.
Training	Hours_of_individual_training	hour/month/man	This flow keeps track of how many training hours will be added to the stock of experience. For now, this is just the amount each worker spends on training that is paid for.
Sector Calculating and perceiving revenue			
Initial_perceived_revenue	Revenue_in_BAU	$/month	Inital Value of the perceived revenue stock. Corresponds to the revenue in the scenario without training (BAU, which is not dynamics but kept as a constant here). The value is calibrated to fit the definition of the EU for small sized businesses (Europäische Kommision 2003)
Measuring_revenue	(revenue-Perceived_revenue_per_month)/Time_to_measure_revenue	$/month/Month	Equation: (revenue-Perceived_revenue_per_month)/Time_to_measure_revenue Unit: $/month/month Calculates the amount that is added or deducted from the perceived revenue stock. This represents and information delay formulation that ensures that with a measuring period of one quart of the year the company measures and updates its revenue.
Perceived_revenue_per_month (t)	Perceived_revenue_per_month(t - dt) + (Measuring_revenue) * dt	$/month	Initial: Initial perceived Revenue (revenue per Month from before any training (BAU)) Stock that represents the perceived value of monthly revenue which is at the disposal for reinvestment. This is part of a information delay, as the company is measuring their revenue not constantly but every quarter to assess their situation. The stock is influenced be the measuring revenue flow that adds (or substracts) the gap between the

			current revenue and what is perceived by the company.
revenue	Total_monthly_output*Sales_Price_per_Unit	$/month	Equation: Total_monthly_output*Sales_Price_per_Unit Unit: $/month The amount of money the company is generating given their workforce, productivity and salesprice. From this, the fraction for competence building is calculated. Initially, this is so the yearly revenue will coincide with the EU Commission Definition of small sized business (EU Commission, 2003). (10Mio./12 = 833.333)
Revenue_in_BAU	Normal_Productivity*Number_of_Workers*(Number_of_Workers*Standard_Working_Hours_per_Month)*Sales_Price_per_Unit	$/month	Equation: Normal_Productivity*Number_of_Workers*(Number_of_Workers*Standard_Working_Hours_per_Month)*Sales_Price_per_Unit Unit: $/month Represents the revenue per month the company made in their old fashion of working. This means it takes into account the number of workers, the sales price, the normal productivity and the standard working hours per month. This number reflects the definition of the EU for small size companies with a revenue of 10mio. per year and less (Europäische Kommision 2003).
Sales_Price_per_Unit	3.254	$/unit	Exogenous parameter that is assumed and is orientated to represent a company in the small-size range. This is to get some backed up estimates about number of workers and revenue per month. The European Commision defines a small size business as a company with less than 50 employees and an annual revenue of less then 10 Mio. € (EU Commission, 2003). The Number of SalesPrice per Unit is calibrated to fit a revenue of 10 Mio€/$ per year (12 Months) under the normal productivity and by that the definition of the EU for small size businesses (Europäische Kommision 2003). The exchange rate from EUR to US$ is neglected in the model.
Time_to_measure_revenue	3	month	Assumed Value based on the assumption, that the company does not measure its monthly revenue constantly but does so on a three month basis which relates to a quarterly assessment of the revenue in order to reallocate ressources.

Total_monthly_output	Productivity_of_Workforce_per_hour*(Time_Spent_Working*Number_of_Workers)	unit/Months	Equation: Productivity_of_Workforce_per_hour*(Time_Spent_Working*Number_of_Workers) Unit: Unit/months Calculates the amount of units that are the output of the hours each worker spends working, giving their productivity. That structure follows logical thinking about productivity, time spent working and the number of workers.
Sector Productivity			
Measuring_Productivity	(Productivity-perceived_productivity_per_worker)/Time_to_measure_productivity	unit/hour/man/Month	Flow - Information Delay. Since the company has no immediate and continuous insight in the productivity of each worker, the productivity perceived by the management is measured and update via this flow every quarter of the year.
Normal_Productivity	1	Unit/hour/man	The basic productivtiy the workers had before the change was initiated. Altough this may seem debatable it is reasonable to put this value to one to assume and indicate that the workers used 100% of there possible productivity before.
Number_of_Workers	40	man	Exogenous parameter that is assumed and is orientated to represent a company in the small-size range. This is to get some backed up estimates about number of workers and revenue per month. The European Commision defines a small size business as a company with less than 50 employees and an annual revenue of less then 10 Mio. The value is calibrated to fit this definition in combination with sales price and productivity (Europäische Kommision 2003).
perceived_productivity_per_worker(t)	perceived_productivity_per_worker(t - dt) + (Measuring_Productivity) * dt	unit/hour/man	Stock - Information Delay Perceived Productivity keeps track of the productivity of the employees recognized by the company. This is formulated with an simple information delay, since this is something the company needs to track repeatedly via measurements. Assuming, that the company assesses its stats every quarter, this is the time with which the perceived productivity is updated.
Productivity	Normal_Productivity*effect_of_agile_competence_on_productivity	unit/hour/man	Equation: Normal_Productivity*effect_of_agile_competence_on_productivity Unit: unit/hour/man

			Represents the current productivity of the workers. The higher the effect of agile competence, the higher the productivity. In the beginning, the effect leads to a reduction of productivity (0.8*normal productivity). With the effect increasing, the productivity is increasing
Productivity_of_Workforce_per_hour	Productivity*Number_of_Workers	unit/Hour	Equation: Productivity*Number_of_Workers Unit: Unit / hour Calculates the unit that the workforce can produce per hour. Therefor the productivity of each worker is multiplied by the number of workers. The structure follows the logical thinking of productivity.
Relative_Productivity	perceived_productivity_per_worker/Normal_Productivity	dmnl	Equation: perceived_productivity_per_worker/Normal_Productivity Unit: Dimensionless This represent the relative productivity the workers have based on the normal productivity and the current perceived productivity by the management.
Standard_Working_Hours_per_Month	160	hour/month/man	Amount of hours each worker has per month. This relates to a standard workweek of 4 weeks, 5 days per month and a standard workday of 8 hours per day
Time_Spent_Working	Standard_Working_Hours_per_Month-Hours_of_individual_training	hour/month/man	Equation: Standard_Working_Hours_per_Month-Hours_of_individual_training Units: hour/month/man Calculates the amount of hours each worker has at their disposal for working. This is the standard workmonth of 160 hours per month per worker minus the hours each worker has training during this month.
Time_to_measure_productivity	3	Month	Time it takes for the company to recognize the change in productivity of their workers. The value is an assumption but is based on the premise that the management assess the stats of the company every quarter.
Initial_Perceived_productivitiy	1	unit/hour/man	Initial Value of perceived productivity. This corresponds to the normal productivity.

Run Specs

Start Time	0
Stop Time	36
DT	1/16
Fractional DT	True
Save Interval	0.0625
Sim Duration	1.5
Time Units	Month
Pause Interval	0
Integration Method	RK4
Track flow quantities	True
Keep all variable results	True
Run By	Run
Calculate loop dominance information	True
Exhaustive Search Threshold	1000

Simulation Experiment Report

Modelling Softwarte: Stella Architect
Integration Method: RK4
DT= 1/16
Time Units = Month
Start Time = 0
Stop Time = 36

Baseline Scenario:

Building Agile Competence Sector

Time it takes forgetting and unlearning = 3
Experience per man for reaching high competence = 100
Normal Agil Competence = 0.5
Time to measure skill progress = 3
Expected Skill Leve = 1
Initial Accumulated Experience = 0

Productivtiy Sector:

Number of Workers = 40
Normal Productivity = 1
Standard Working Hours per month = 160
Time to measure productivity = 3

Calculating and perceiving revenue sector:

Time to measure revenue = 3
Sales Price per Unit = 3.254
Initial perceived Revenue: 833.024

Allocating Ressources for Competence Building Sector:

Weight on SkillBuilding = 0.5
BudgetBoost = 0.01
Normal fraction of budget for L&D = 0.035
BudgetBoostSwitch = 0
Average hour per Worker on L&D per Month = 35/12
Average Cost per Worker on L&D per month = 1270/12
Max hours of training per Month = 40

BudgetBoost Scenario

This scenario activates the policy switch for the budget boost from the outset of the simulation. All parameters and initial values are kept as before except:

BudgetBoostSwitch = 1

DesiredRun Scenario

This “scenario” produces the assumed desired behavior of almost no performance dip and revenue dip. As can be seen in the changed parameters, the values are calibrated to fit the desired story, but not backed up by literature (The outset assumes, that the workers already have knowledge of the skill (their initial knowledge) leading to no reduction in productivity and can hold their skill longer (forgetting time is increased)

All parameters are as in the initial scenario expect:

Initial Accumulated Experience = 50
Time it takes forgetting and unlearning = 5

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