

# **A Dynamic View on Knowledge Development: A Case of Industrial Aerospace Supply Chain Development in Indonesia**

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## ***Abstract***

*Indonesia, through a state-owned aircraft industry named PT. Dirgantara Indonesia (PTDI), plans to develop its national capacity in aerospace industrial technology. The strategy to realize this objective is to build an aerospace supply chain of industries through which the Small & Medium Enterprises (SME) can have a role in the global aerospace supply chain market in the near future. As a main focus for this purpose, the Quality Management Systems (QMS), like AS 9100, has to be internalized in the SME; because, in reality, the Indonesian SME have no experience with quality requirements. Therefore, it is important to introduce the QMS learning process to the SME through an outsourcing collaboration between PTDI and SME. To begin the learning process, a systems model for knowledge development will be presented based on the inter-organizational learning dynamic model developed by Otto and Richardson in 2004. Modifications of the original model are made to accommodate an assistance mechanism for the SME learning process due to their lack of knowledge in quality control. This specific knowledge is essential to accomplish the outsourcing partnership between PTDI and the SME. This study shows the importance of PTDI's influence in educating the SME in quality control through a quality management systems program (QMS) for the purpose of Indonesia entering the global aerospace supply chain industry.*

**Keywords:** *Aerospace, Assistance, Inter-organizational Learning, Knowledge Development, Small & Medium Enterprises, Supply Chain, System Dynamics*

## **Introduction**

PT. Dirgantara Indonesia (Persero), abbreviated PTDI, Indonesia's national aerospace company, plans to develop a supply chain of industries that support the major Indonesian aerospace industry. The plan is to improve the quality of aerospace components manufactured by many small and medium sized companies in order for Indonesia to strike a more prominent role in global markets. Quality control and management are the key points to be addressed and internalized. In reality, the smaller companies that support the aerospace industry have not yet experienced good quality control. It is important to introduce a quality management system for collaboration and uniformity between PTDI and the smaller companies already supporting the aerospace industry. In order to simulate the learning process for building an Indonesian global aerospace supply chain, a system dynamics model is constructed based on the inter-organizational learning model developed by Otto and Richardson (2004). This study shows that professional assistance is imperative for the smaller companies that lack prior knowledge and experience in quality management. The assistance will not only work as a catalyst to accelerate the collaboration process, but also act as a focal point for the unified businesses.

From its beginning, PTDI successfully carried out aerospace technology transformations and other business missions. This early success allowed PTDI to be commercially competitive and enhanced Indonesia's national aerospace reputation.

The economic and monetary crisis that occurred in Southeast Asia in the late 1990's had a significant impact on the multi-dimensional crisis in Indonesia. The effects of the government shifting its main focus from industrial development to the prosperity of its citizens changed the nation's aerospace forward progress. A "Letter of Intent" (January 15, 1998) from the International Monetary Fund (IMF) changed the development of Indonesia's aerospace industry which was still developing at that time. Termination of government subsidies to the aerospace industry caused many critical problems, including brain-drain, stagnant research and dormant assets.

To overcome the crisis, PTDI has successfully reconstructed the company. PTDI not only focused on the development of the aircraft, but it evolved into four main business groups: **Aero Structure**, focused on business aircraft components; **Aircraft Integration**, focused on the assembly for aircraft and helicopters; **Aircraft Services**, focused on maintenance; and **Technology and Development** focused on systems engineering and weapons. Restructuring the company has shown that PTDI is capable of taking part globally in an aerospace supply chain industry with extended shops and subcontractors in aircraft components production. Several long-term contracts have been achieved, for example: contracts with Aerocoverters (France), Spirit Aerosystems (UK), CTRM (Malaysia), Malaysian Paragon-SMEA (Malaysia), Boeing (USA), AVCEN Limited (Malaysia) and Korean Air (Korea). Not only that, PTDI has also

become the exclusive supplier for the manufacture of Airbus A380 Wing Inboard Outboard Fixed Leading Edge.

As a major aerospace industry in Indonesia, PTDI has the ability to build a national market by developing an industrial supply chain with partners that manufacture aircraft components. The outsourcing cooperation between PTDI with one of the SME in Indonesia, PT. Ina Indotech Engineering (IEE), resulted in manufacturing tools for producing NC 212-400 aircraft in 2009. It has succeeded in empowering IIE to become an independent aerospace supply chain industry. This is evidenced by the success of IEE in earning the Certified Distributor of Aeronautical Products certificate from the Directorate General of Air Communications (DGAC), Ministry of Transportation of Indonesia as a competent institution in Indonesia.

In this paper, the learning process in strategic cooperation between PTDI as a main industry and Small & Medium Enterprises (SME) as supply chain industry partners will be simulated using the system dynamics model. This model will give a deeper understanding of the important aspects that affect the process of outsourcing collaboration in building an aerospace supply chain industry. The dynamic behavior of inter-organizational learning between PTDI and SME will be examined using a system dynamics approach. A detailed description of the model will be elaborated upon in the next chapter.

### **An Inter-organizational Learning between PTDI-SME Frameworks**

To take part in the global aerospace industry, the aerospace quality management system (QMS) known as AS9100 is a system that should be understood and practiced by the SME. The system can be learned and absorbed more quickly through an outsourcing partnership between PTDI and SME in terms of “learning-by-doing.” This learning process in mastering the Quality Management Systems by SME will be modeled using system dynamics methodology.

The model was adapted from the Inter-organizational Learning Model developed by Otto and Richardson (2004). Modifications conducted in the model are based on interviews with several participants in the outsourcing program and enriched with several literature reviews. Learning objectives between PTDI and SME are dependent on the learning abilities and the cooperative strategies adopted both by PTDI and SME in mastering the quality management systems (AS 9100) as the prerequisite for an aerospace supply chain industry. The cooperation strategy must be based on mutual trust as well as the willingness to share existing knowledge (combination of explicit knowledge and tacit knowledge of experience).

The success of the strength of SME through an outsourcing partnership with PTDI will bring a level of new knowledge and experience with better uniform quality control

formed in each company. Periodic evaluations need to be conducted in order to ascertain the progress of learning through this assistance program. The feedback view of PTDI and SME showing their combined organizational actions in forming new knowledge and experiences from an outsourcing partnership are visualized in Figure 1.

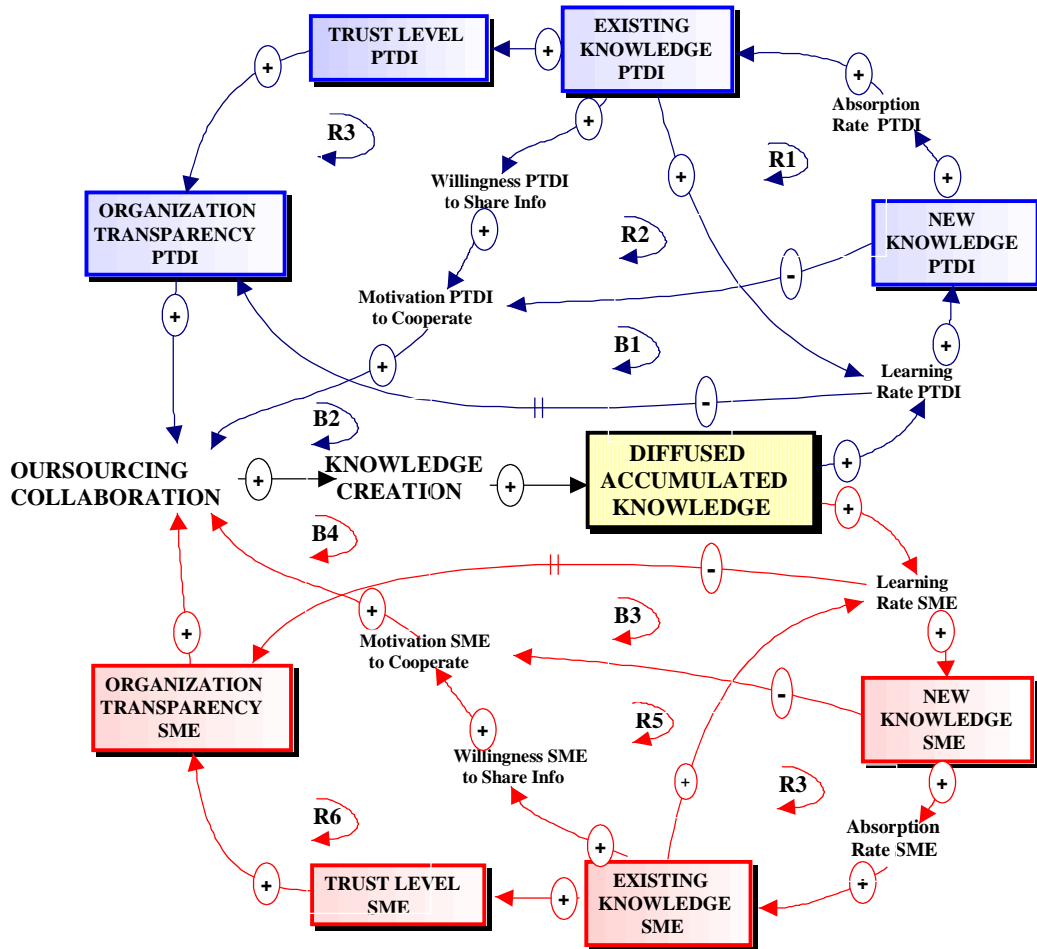


Figure 1 Causal feedback loop framework for inter-organizational learning between PTDI and SME

During the outsourcing collaboration process between PTDI and SME, inter-organizational learning can be achieved by transferring existing knowledge and experience from PTDI to SME, as well as creating completely new knowledge through interaction between them. This learning process will produce excellent competitive quality products in accordance to the aerospace quality standards and regulations, AS 9100, such as changing in the pattern and work culture of SME that concern tracking and general safety.

The collaborative process creates the alliance knowledge which in turn leads to diffused accumulated knowledge. The level of collaboration is determined by the transparency of each firm as well as the levels of their motivation to cooperate, reinforcing loop R2 for PTDI and R5 for SME partners. If the firm is not transparent, no existing knowledge will be given and thereby no learning process can be generated; furthermore no new knowledge is generated. Transparency in a firm is a choice, determined mainly by the individual trust level of each firm which is influenced by the existing knowledge level of knowledge. As the organization gains new knowledge, the level of existing knowledge will be increased and trust grows. The lack of inter-organizational trust is, therefore, a barrier to organizational knowledge creation (reinforcing loop R3 for PTDI and R6 for SME partner). The learning rate level is influenced by diffused accumulated knowledge and also by the existing knowledge of an organization. Thus, the absorptive capacity of a firm is considered as a limiting ability factor of organizational learning (balancing loop B1 for PTDI and B3 for SME partner).

The two variables “willingness to share” and “motivation to cooperate” can either positively influence the level of cooperation between the allied partners, while the level of existing knowledge determines the willingness to share and new knowledge influences the motivation to cooperate. The balancing loop B2 for PTDI and B4 for SME in figure 1 suggests that gaining new knowledge may reduce the motivation to cooperate. The new knowledge gained by one partner resulting in opportunities can reduce the motivation to cooperate, and thus encourages the withholding of knowledge from the other partner.

Furthermore, the motivation to cooperate linked existing knowledge with “willingness to share” variable, represents the level of existing knowledge which influences the level of willingness of an organization to share its knowledge with their partners.

### **Model Structure**

This model shows the new knowledge and trust created during an outsourcing collaboration between PTDI and SME. Figure 2 below illustrates the establishment of jointly created knowledge, diffused accumulation knowledge and inter-organizational trust.

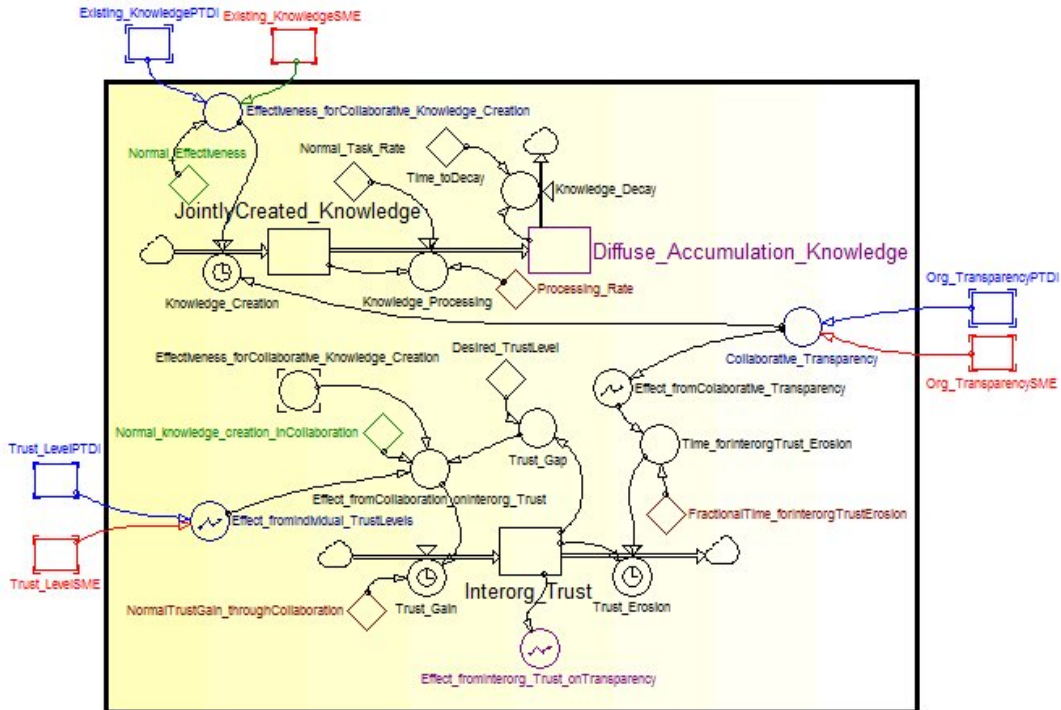


Figure 2 Conceptualization of outsourcing collaboration for knowledge and trust creation between PTDI-SME

Jointly created knowledge is conceptualized as a stock with an inflow from knowledge learning creation rate that influences the effectiveness for joint knowledge creation and collaborative transparency during the outsourcing process. The outflow from jointly created knowledge, plus knowledge gained from the learning process, become an inflow for diffused accumulated knowledge, then the knowledge learning decay-rate become its outflow. Inter-organizational trust is conceptualized as a stock with an inflow from the trust gained by the cooperation with partners that are influenced through collaboration and the inflow effect from collaboration on inter-organizational trust. The outflow from the stock of inter-organizational trust shows trust erosion that is influenced by the variable “effect from collaborative transparency.” Inter-organizational trust is increased through the trust levels of the two partners and decreased through collaborative transparency.

Figure 3 Illustrates how new knowledge and organizational transparency and trust of PTDI is created. Figure 4 (identical with Figure 3) illustrates how new knowledge, organizational transparency and trust of SME is created.

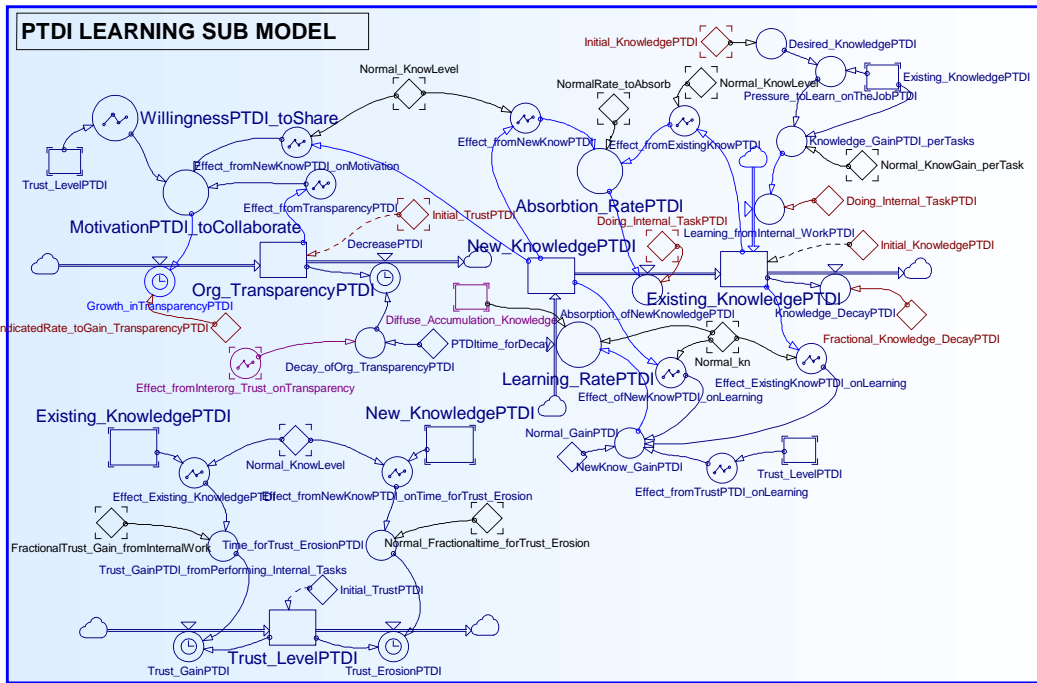


Figure 3 Conceptualization of PTDI knowledge and trust creation through outsourcing collaboration

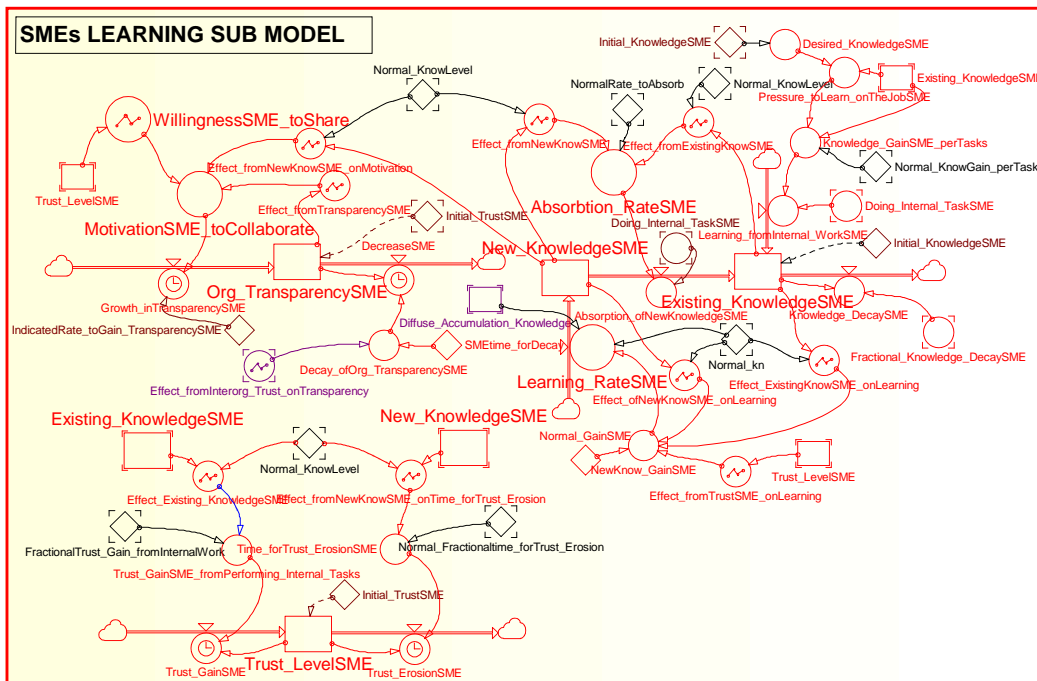


Figure 4 Conceptualization of SME knowledge and trust creation through outsourcing collaboration

Meanwhile, existing knowledge conceptualized as stock with an inflow from “learning-while-doing-internal-tasks” and another inflow from “absorbing-new-knowledge” gained during an outsourcing partnership. For the outflow, its use as a constant fractional knowledge decay to capture an obsolescence rate for organizational knowledge. The level of existing knowledge influences the absorption rate of new knowledge and the learning rate which is diffused in the accumulated knowledge acquired.

New knowledge is determined by the learning rate and constrained by the level of diffused accumulated knowledge that is created during the partnership. The learning rate of new knowledge is based on the trust level and the level of existing knowledge; furthermore, the level of new knowledge then determines the motivation rate. Gaining new knowledge may eventually reduce the motivation to cooperate. In turn, motivation to collaborate and willingness to share information influence the level of organizational transparency that is provided by the firm during the alliance. The outflow from the stock of organizational transparency of PTDI or SME is determined by the level of inter-organizational trust. It is a rate of trust created between PTDI and SME during the collaboration. The learning rate of new knowledge is then influenced by partner intentions and ability to learn, as well as the trust acquired by the firm in the partnership. The trust level of a partner is then determined by the initial existing knowledge and the newly gained knowledge.

### **Model Behavior**

This section describes the simulation of the system dynamics model of inter-organizational learning. Various factors that influence the acquisition of learning in an outsourcing partnership between PTDI and SME will be simulated to understand the role of assistance in improving the SME’s lack of knowledge. The simulation includes the base run, the effect of SME initial lack of knowledge, the effect of initial lack of trust of SME and the assistance to improve SME initial knowledge scenarios.

#### **➤ Base Reference Run**

The base run simulation shows the key variables and their expected behavior of a successful outsourcing partnership between PTDI and SME in building the aerospace supply chain industries. Figure 5 shows the base run simulation results.



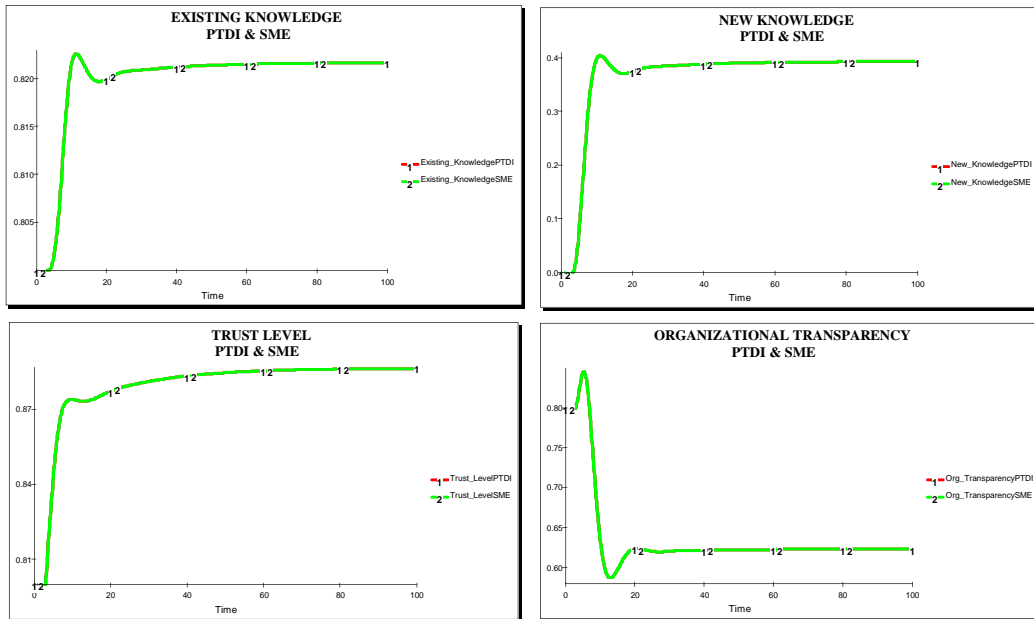


Figure 5 Base Reference Run simulation results.

Scale 0 to 1.0 is used to capture the initial conditions for knowledge and trust level. The base run simulation that represents an expected successful behavior during the outsourcing partnership between PTDI and SME occurs on variables of initial knowledge and the trust level that is equal to 0.8.

The results from this base run shows that PTDI and SME will gain new knowledge and thus slightly increase their level of existing knowledge. Organizational transparency oscillates by rising and dropping and then rises again due to interplays between the delays in gaining new knowledge and the waning and waxing of the firm’s motivations to collaborate. As PTDI and SME gain new knowledge, their trust level increases and remains high as long as new knowledge continues to be created. The new knowledge level is used as a main indicator of successful outsourcing partnership.

**Inadequate SME Initial Knowledge Effect**

The following simulation is for conditions in which SME has inadequate prior knowledge and experience, especially in the control of QMS requiring traceability and a safety culture. The simulation results are observed in Figure 6.

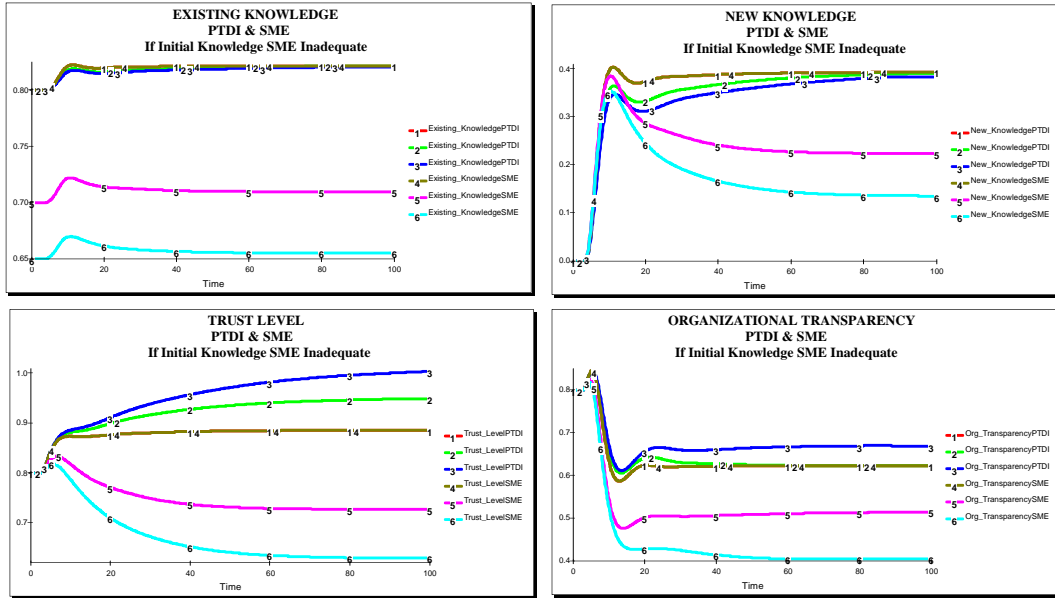


Figure 6 Simulation results if SME initial knowledge inadequate

Line 5 illustrates the simulation results for the initial knowledge SME = **0.7** and line 6 for initial knowledge SME = **0.65**. Apparently if the prior knowledge required is far from the expectation ( $< 0.8$ ), then the trust level and organizational transparency will increasingly disappear. It can be seen in Figure 6 that shows the trust level and the organizational transparency graph decreasing to zero.

From this simulation, it can be concluded that an outsourcing partnership is not likely to succeed because of the inadequate initial knowledge of the SME. This simulation also gives sense the intervention is needed to improve the understanding of SME for aerospace quality management system, AS 9100.

**Inadequate SME Initial Trust Effects**

The scenario of initial trust levels used for the simulation starting from **0.7** for the SME then continued by **0.65**, in order to check the results of the conditions of SME starting the partnership with doubts.

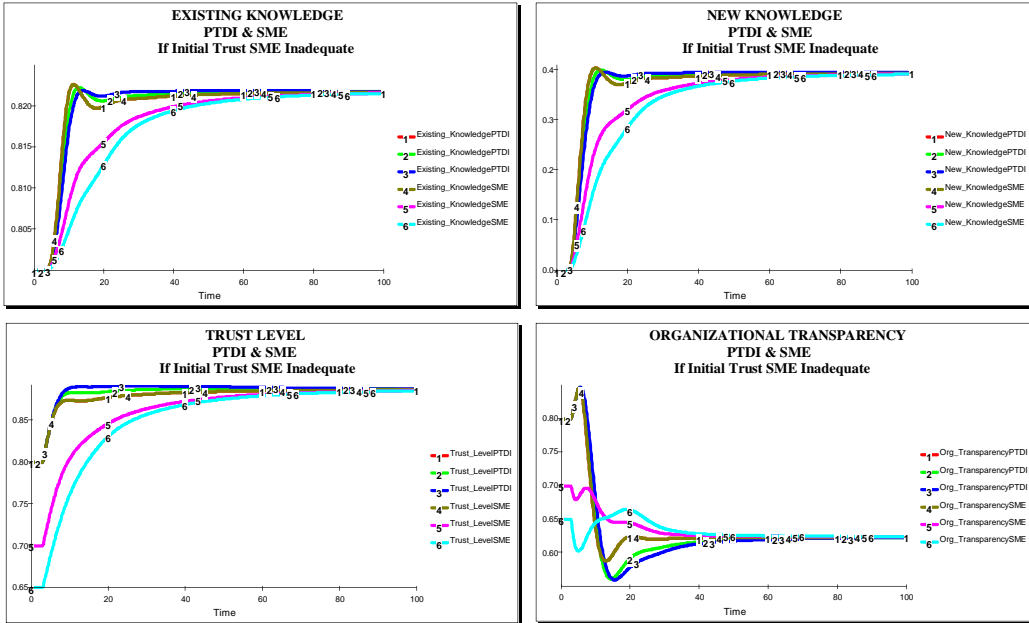


Figure 7 Simulation results if initial trust of SME is inadequate

Figure 7 is show that although SME had a low level of trust at the beginning, new knowledge can increase the trust level depending on the knowledge gained by the SME. Not only the trust level, but the organizational transparency will increase, thereby removing the need for any intervention.

### Assistance to Improve SME Initial Knowledge

From the previous simulation scenario, it can be understood that the SME needs to have adequate knowledge and experience in QMS prior to the outsourcing partnership with PTDI. This can be done by providing training and mentoring before the cooperation is conducted and makes it possible to know the limited ability of SME in the ongoing cooperation.

The following simulation shows the impact of PTDI assistance on SME. The assistance is given by a group of trained personnel who already understand the QMS and can accelerate the improvement of knowledge and abilities of the SME.

To simulate the behavior of inter-organizational learning with QMS assistance, the assistance structure needed to be added to the original model (shown in Figure 8 as a sub-model structure of assistance.) Now the simulation results can be observed in Figure 9.

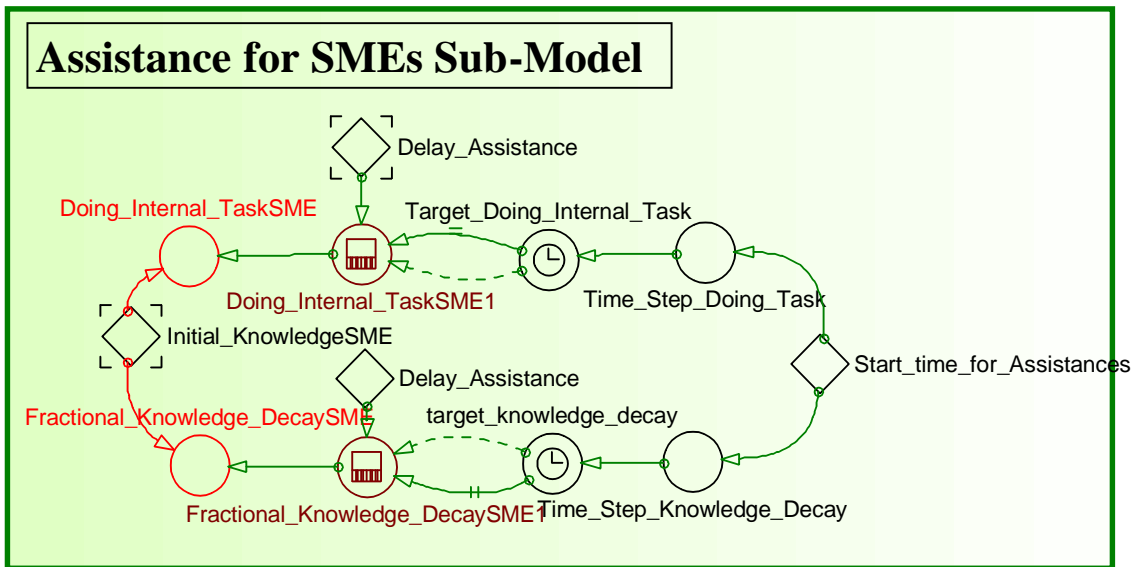


Figure 8 Conceptualization of Assistance for SME

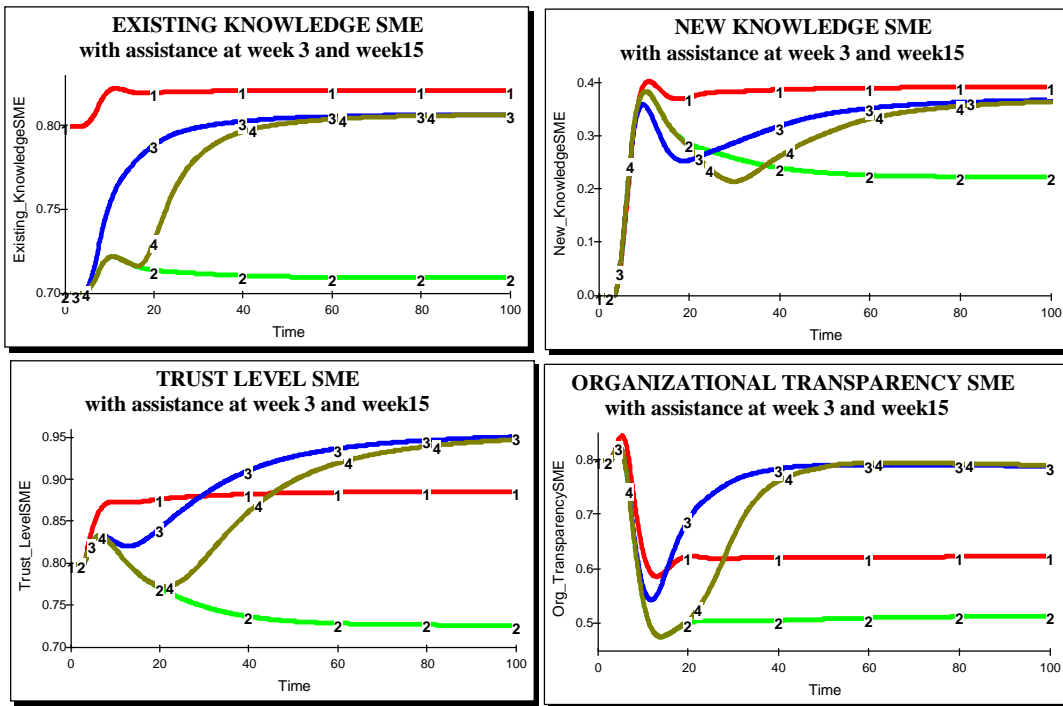


Figure 9 SME Simulation results with assistance for SME

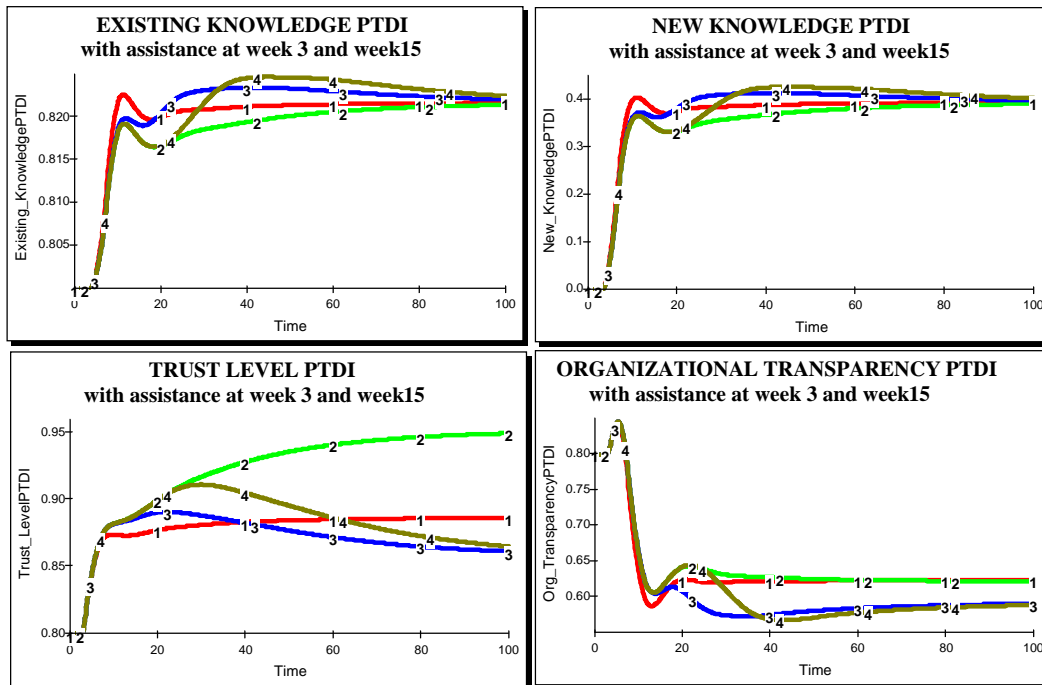


Figure 10 PTDI Simulation result with assistance for SME

*Remarks:* Line 1 shows the base run. Line 2 shows conditions before the assistance was given. Line 3 shows the assistance started on week 3. Line 4 shows the assistance that started at week 15.

The simulation shows major differences between the numbers of weeks of intervention assistance. It can be concluded that mentoring by a group of trained personnel with adequate experience can enhance the ability of SME to understand and master the working culture required in the QMS program for the aerospace industry. Thus, assistance should be given as early as possible before the willingness to cooperate and the trust level of the organizational transparency fail.

## Conclusion

From the simulation, it is concluded that the initial knowledge and experience, willingness to share and the motivation to cooperate generated by SME are the key aspects in the success of outsourcing partnerships between PTDI and SME. The confidence and trust will increase along with the increased benefits and added value gained from outsourcing partnerships. The basic initial knowledge is something that must be held by the SME in order to build an aerospace supply chain industry. Inadequate initial knowledge can be enhanced through QMS learning assistance resulting in an increase in the pace of the knowledge absorbed by the SME. The need for this assistance will open employment opportunities for former employees of PTDI and also other professionals in the aerospace field.

For Indonesia, developing aerospace quality management systems that do not yet exist in the SME, additional assistance is essential since it will increase the knowledge and experience of SME. While the assistance could be conducted by the former employees, the assistance should also be conducted at the earliest time to get SME to master the QMS more quickly. As the SME attain the culture of QMS, the goal to build a global aerospace supply chain can be achieved. The development of an Indonesian aerospace supply chain industry in which SME are the key point will, in the long term, develop a national capacity for building the aerospace industry. This means that the goal of the nation to advance in the field of aerospace can be achieved.

## Appendix: Equation for Simulation Model

```

init    Diffuse_Accumulation_Knowledge = 0
flow    Diffuse_Accumulation_Knowledge = - dt*Knowledge_Decay + dt*Knowledge_Processing
init    Existing_KnowledgePTDI = Initial_KnowledgePTDI
flow    Existing_KnowledgePTDI = + dt*Absorption_ofNewKnowledgePTDI -
        dt*Knowledge_DecayPTDI + dt*Learning_fromInternal_WorkPTDI
init    Existing_KnowledgeSME = Initial_KnowledgeSME
flow    Existing_KnowledgeSME = -dt*Knowledge_DecaySME + dt*Absorption_ofNewKnowledgeSME
        +dt*Learning_fromInternal_WorkSME
init    Interorg_Trust = 0
flow    Interorg_Trust = - dt*Trust_Erosion + dt*Trust_Gain
init    JointlyCreated_Knowledge = 0
flow    JointlyCreated_Knowledge = - dt*Knowledge_Processing + dt*Knowledge_Creation
init    New_KnowledgePTDI = 0
flow    New_KnowledgePTDI = - dt*Absorption_ofNewKnowledgePTDI + dt*Learning_RatePTDI
init    New_KnowledgeSME = 0
flow    New_KnowledgeSME = + dt*Learning_RateSME - dt*Absorption_ofNewKnowledgeSME
init    Org_TransparencyPTDI = Initial_TrustPTDI
flow    Org_TransparencyPTDI = + dt*Growth_inTransparencyPTDI - dt*DecreasePTDI
init    Org_TransparencySME = Initial_TrustSME
flow    Org_TransparencySME = + dt*Growth_inTransparencySME - dt*DecreaseSME
init    Trust_LevelPTDI = Initial_TrustPTDI
flow    Trust_LevelPTDI = - dt*Trust_ErosionPTDI + dt*Trust_GainPTDI
init    Trust_LevelSME = Initial_TrustSME
flow    Trust_LevelSME = +dt*Trust_GainSME - dt*Trust_ErosionSME
aux     Absorption_ofNewKnowledgePTDI = Absorbtion_RatePTDI*Doing_Internal_TaskPTDI
aux     Absorption_ofNewKnowledgeSME = Absorbtion_RateSME*Doing_Internal_TaskSME
aux     DecreasePTDI = STEP(Org_TransparencyPTDI*Decay_ofOrg_TransparencyPTDI,3)
aux     DecreaseSME = STEP(Org_TransparencySME*Decay_ofOrg_TransparencySME,3)
aux     Growth_inTransparencyPTDI =
        STEP(IndicatedRate_toGain_TransparencyPTDI*MotivationPTDI_toCollaborate,3)
aux     Growth_inTransparencySME =
        STEP(IndicatedRate_toGain_TransparencySME*MotivationSME_toCollaborate,3)
aux     Knowledge_Creation =
        STEP(Effectiveness_forCollaborative_Knowledge_Creation*Collaborative_Transparency,3)
aux     Knowledge_Decay = Diffuse_Accumulation_Knowledge/Time_toDecay

```

aux Knowledge\_DecayPTDI = Existing\_KnowledgePTDI\*Fractional\_Knowledge\_DecayPTDI  
 aux Knowledge\_DecaySME = Existing\_KnowledgeSME\*Fractional\_Knowledge\_DecaySME  
 aux Knowledge\_Processing = JointlyCreated\_Knowledge\*Processing\_Rate\*Normal\_Task\_Rate  
 aux Learning\_fromInternal\_WorkPTDI=  
 Doing\_Internal\_TaskPTDI\*Knowledge\_GainPTDI\_perTasks  
 aux Learning\_fromInternal\_WorkSME=  
 Doing\_Internal\_TaskSME\*Knowledge\_GainSME\_perTasks  
 aux Learning\_RatePTDI = Diffuse\_Accumulation\_Knowledge\*NewKnow\_GainPTDI/Normal\_kn  
 aux Learning\_RateSME = Diffuse\_Accumulation\_Knowledge\*NewKnow\_GainSME/Normal\_kn  
 aux Trust\_Erosion = STEP(Interorg\_Trust/Time\_forInterorgTrust\_Erosion,3)  
 aux Trust\_ErosionPTDI = STEP(Trust\_LevelPTDI/Time\_forTrust\_ErosionPTDI,3)  
 aux Trust\_ErosionSME = STEP(Trust\_LevelSME/Time\_forTrust\_ErosionSME,3)  
 aux Trust\_Gain=  
 STEP(Effect\_fromCollaboration\_onInterorg\_Trust\*NormalTrustGain\_throughCollaboration,3)  
 aux Trust\_GainPTDI=  
 STEP(Trust\_GainPTDI\_fromPerforming\_Internal\_Tasks\*Trust\_LevelPTDI,3)  
 aux Trust\_GainSME= STEP(Trust\_GainSME\_fromPerforming\_Internal\_Tasks\*Trust\_LevelSME,3)  
 aux Absorbtion\_RatePTDI=  
 Effect\_fromExistingKnowPTDI\*Effect\_fromNewKnowPTDI\*NormalRate\_toAbsorb  
 aux Absorbtion\_RateSME=  
 Effect\_fromExistingKnowSME\*Effect\_fromNewKnowSME\*NormalRate\_toAbsorb  
 aux Collaborative\_Transparency = Org\_TransparencyPTDI\*Org\_TransparencySME  
 aux Decay\_ofOrg\_TransparencyPTDI=  
 Effect\_fromInterorg\_Trust\_onTransparency/PTDItime\_forDecay  
 aux Decay\_ofOrg\_TransparencySME=  
 Effect\_fromInterorg\_Trust\_onTransparency/SMEtime\_forDecay  
 aux Desired\_KnowledgePTDI = Initial\_KnowledgePTDI+0.1  
 aux Desired\_KnowledgeSME = Initial\_KnowledgeSME+0.1  
 aux Doing\_Internal\_TaskSME = IF(Initial\_KnowledgeSME>=0.8,4,Doing\_Internal\_TaskSME1)  
 aux Doing\_Internal\_TaskSME1=  
 DELAYINF(Target\_Doing\_Internal\_Task,Delay\_Assistance,3,Target\_Doing\_Internal\_Task)  
 aux Effect\_Existing\_KnowledgePTDI=  
 GRAPHCURVE(Existing\_KnowledgePTDI/Normal\_KnowLevel,0,0.1,[0,0.187919,0.359496,0.  
 510331,0.640424,0.749775,0.838384,0.906251,0.953376,0.979759,1"Min:0;Max:1;Zoom"])  
 aux Effect\_Existing\_KnowledgeSME=  
 GRAPHCURVE(Existing\_KnowledgeSME/Normal\_KnowLevel,0,0.1,[0,0.187919,0.359496,0.  
 510331,0.640424,0.749775,0.838384,0.906251,0.953376,0.979759,1"Min:0;Max:1;Zoom"])  
 aux Effect\_ExistingKnowPTDI\_onLearning=  
 GRAPHCURVE(Existing\_KnowledgePTDI/Normal\_kn,0,0.1,[1,0.998443,0.975032,0.929867,0.  
 862948,0.774275,0.663848,0.531667,0.377732,0.202043,0"Min:0;Max:1;Zoom"])  
 aux Effect\_ExistingKnowSME\_onLearning=  
 GRAPHCURVE(Existing\_KnowledgeSME/Normal\_kn,0,0.1,[1,0.998443,0.975032,0.929867,0.  
 862948,0.774275,0.663848,0.531667,0.377732,0.202043,0"Min:0;Max:1;Zoom"])  
 aux Effect\_fromColaborative\_Transparency=  
 GRAPHCURVE(Collaborative\_Transparency,0,0.1,[1,0.979134,0.944032,0.891933,0.822172,0.  
 734088,0.627016,0.500295,0.35326,0.18525,0"Min:0;Max:1;Zoom"])  
 aux Effect\_fromCollaboration\_onInterorg\_Trust=  
 Effect\_fromIndividual\_TrustLevels\*Effectiveness\_forCollaborative\_Knowledge\_Creation\*  
 Trust\_Gap/Normal\_knowledge\_creation\_inCollaboration

aux Effect\_fromExistingKnowPTDI=  
 GRAPHCURVE(Existing\_KnowledgePTDI/Normal\_KnowLevel,0,0.1,[0,0.181244,0.323756,0.453056,0.569084,0.6719,0.761484,0.837836,0.900956,0.950844,1"Min:0;Max:1;Zoom"])

aux Effect\_fromExistingKnowSME=  
 GRAPHCURVE(Existing\_KnowledgeSME/Normal\_KnowLevel,0,0.1,[0,0.181244,0.323756,0.453056,0.569084,0.6719,0.761484,0.837836,0.900956,0.950844,1"Min:0;Max:1;Zoom"])

aux Effect\_fromIndividual\_TrustLevels=  
 GRAPH(Trust\_LevelPTDI\*Trust\_LevelSME,0,0.1,[0,0.0214887,0.0328115,0.0527385,0.087023,0.1352406,0.1976266,0.2819144,0.4101741,0.6256502,1,1,1,1,1"Min:0;Max:1.1;Zoom"])

aux Effect\_fromInterorg\_Trust\_onTransparency=  
 GRAPHCURVE(Interorg\_Trust,0,0.1,[1,0.9999524,0.9284912,0.8139488,0.6707576,0.51335,0.3561584,0.2136152,0.100528,0.0302036,0"Min:0;Max:1;Zoom"])

aux Effect\_fromNewKnowPTDI=  
 GRAPHCURVE(New\_KnowledgePTDI/Normal\_KnowLevel,0,0.1,[0,0.03001,0.07024,0.12709,0.20056,0.29065,0.39736,0.52069,0.66064,0.81721,1"Min:0;Max:1;Zoom"])

aux Effect\_fromNewKnowPTDI\_onMotivation=  
 GRAPHCURVE(New\_KnowledgePTDI/Normal\_KnowLevel,0,0.1,[1,0.90674,0.80744,0.7079,0.60812,0.5081,0.40784,0.30734,0.2066,0.10562,0"Min:0;Max:1;Zoom"])

aux Effect\_fromNewKnowPTDI\_onTime\_forTrust\_Erosion=  
 GRAPHCURVE(New\_KnowledgePTDI/Normal\_KnowLevel,0,0.1,[1,0.94152,0.89967,0.86739,0.84484,0.83243,0.83107,0.84244,0.86954,0.91766,1"Min:0;Max:2;Zoom"])

aux Effect\_fromNewKnowSME=  
 GRAPHCURVE(New\_KnowledgeSME/Normal\_KnowLevel,0,0.1,[0,0.03001,0.07024,0.12709,0.20056,0.29065,0.39736,0.52069,0.66064,0.81721,1"Min:0;Max:1;Zoom"])

aux Effect\_fromNewKnowSME\_onMotivation=  
 GRAPHCURVE(New\_KnowledgeSME/Normal\_KnowLevel,0,0.1,[1,0.90674,0.80744,0.7079,0.60812,0.5081,0.40784,0.30734,0.2066,0.10562,0"Min:0;Max:1;Zoom"])

aux Effect\_fromNewKnowSME\_onTime\_forTrust\_Erosion=  
 GRAPHCURVE(New\_KnowledgeSME/Normal\_KnowLevel,0,0.1,[1,0.94152,0.89967,0.86739,0.84484,0.83243,0.83107,0.84244,0.86954,0.91766,1"Min:0;Max:2;Zoom"])

aux Effect\_fromTransparencyPTDI=  
 GRAPHCURVE(Org\_TransparencyPTDI,0,0.1,[0,0.224556,0.404773,0.548793,0.662058,0.75013,0.818098,0.871756,0.916431,0.957565,1"Min:0;Max:1;Zoom"])

aux Effect\_fromTransparencySME=  
 GRAPHCURVE(Org\_TransparencySME,0,0.1,[0,0.224556,0.404773,0.548793,0.662058,0.75013,0.818098,0.871756,0.916431,0.957565,1"Min:0;Max:1;Zoom"])

aux Effect\_fromTrustPTDI\_onLearning=  
 GRAPH(Trust\_LevelPTDI,0,0.1,[0,0.0086346,0.0267272,0.0406404,0.048396,0.057575,0.08853176,0.1583232,0.3128504,0.627193,1,1,1,1,1"Min:0;Max:1.1;Zoom"])

aux Effect\_fromTrustSME\_onLearning=  
 GRAPH(Trust\_LevelSME,0,0.1,[0,0.0086346,0.0267272,0.0406404,0.048396,0.057575,0.08853176,0.1583232,0.3128504,0.627193,1,1,1,1,1"Min:0;Max:1.1;Zoom"])

aux Effect\_ofNewKnowPTDI\_onLearning=  
 GRAPHCURVE(New\_KnowledgePTDI/Normal\_kn,0,0.1,[1,1,0.99168,0.96853,0.926756,0.861413,0.767552,0.640228,0.474492,0.265399,0"Min:0;Max:1;Zoom"])

aux Effect\_ofNewKnowSME\_onLearning=  
 GRAPHCURVE(New\_KnowledgeSME/Normal\_kn,0,0.1,[1,1,0.99168,0.96853,0.926756,0.861413,0.767552,0.640228,0.474492,0.265399,0"Min:0;Max:1;Zoom"])

aux Effectiveness\_forCollaborative\_Knowledge\_Creation=  
 MIN(Existing\_KnowledgePTDI,Existing\_KnowledgeSME)\*Normal\_Effectiveness



```

aux   Fractional_Knowledge_DecaySME=
      IF(Initial_KnowledgeSME>=0.8,0.4,Fractional_Knowledge_DecaySME1)
aux   Fractional_Knowledge_DecaySME1=
      DELAYINF(target_knowledge_decay,Delay_Assistance,3,target_knowledge_decay)
aux   Knowledge_GainPTDI_perTasks=
      Pressure_toLearn_onTheJobPTDI*Existing_KnowledgePTDI/Normal_KnowGain_perTask
aux   Knowledge_GainSME_perTasks=
      Pressure_toLearn_onTheJobSME*Existing_KnowledgeSME/Normal_KnowGain_perTask
aux   MotivationPTDI_toCollaborate=
      Effect_fromNewKnowPTDI_onMotivation*Effect_fromTransparencyPTDI*
      WillingnessPTDI_toShare
aux   MotivationSME_toCollaborate=
      Effect_fromNewKnowSME_onMotivation*Effect_fromTransparencySME*
      WillingnessSME_toShare
aux   NewKnow_GainPTDI=
      Effect_ExistingKnowPTDI_onLearning*Effect_fromTrustPTDI_onLearning*
      Effect_ofNewKnowPTDI_onLearning*Normal_GainPTDI
aux   NewKnow_GainSME=
      Effect_ExistingKnowSME_onLearning*Effect_fromTrustSME_onLearning*
      Effect_ofNewKnowSME_onLearning*Normal_GainSME
aux   Pressure_toLearn_onTheJobPTDI = Desired_KnowledgePTDI-Existing_KnowledgePTDI
aux   Pressure_toLearn_onTheJobSME = Desired_KnowledgeSME-Existing_KnowledgeSME
aux   Target_Doing_Internal_Task = STEP(4,Time_Step_Doing_Task) + 4
aux   target_knowledge_decay = 0.4-STEP(0.3,Time_Step_Knowledge_Decay)
aux   Time_forInterorgTrust_Erosion=
      Effect_fromColaborative_Transparency*FractionalTime_forInterorgTrustErosion
aux   Time_forTrust_ErosionPTDI=Effect_fromNewKnowPTDI_onTime_forTrust_Erosion*
      Normal_Fractionaltime_forTrust_Erosion
aux   Time_forTrust_ErosionSME=Effect_fromNewKnowSME_onTime_forTrust_Erosion*
      Normal_Fractionaltime_forTrust_Erosion
aux   Time_Step_Doing_Task = Start_time_for_Assistances
aux   Time_Step_Knowledge_Decay = Start_time_for_Assistances
aux   Trust_GainPTDI_fromPerforming_Internal_Tasks=
      Effect_Existing_KnowledgePTDI*FractionalTrust_Gain_fromInternalWork
aux   Trust_GainSME_fromPerforming_Internal_Tasks=
      Effect_Existing_KnowledgeSME*FractionalTrust_Gain_fromInternalWork
aux   Trust_Gap = Desired_TrustLevel-Interorg_Trust
aux   WillingnessPTDI_toShare=
      GRAPH(Trust_LevelPTDI,0,0.1,[0,0.07469,0.152276,0.236151,0.326284,0.422675,0.525324,0.
      634231,0.7493964,0.870819,1,1,1,1,1,1"Min:0;Max:1.1;Zoom"])
aux   WillingnessSME_toShare=
      GRAPH(Trust_LevelSME,0,0.1,[0,0.07469,0.152276,0.236151,0.326284,0.422675,0.525324,0.
      634231,0.7493964,0.870819,1,1,1,1,1,1"Min:0;Max:1.1;Zoom"])
const Delay_Assistance = 12
const Desired_TrustLevel = 0.8
const Doing_Internal_TaskPTDI = 4
const Fractional_Knowledge_DecayPTDI = 0.4
const FractionalTime_forInterorgTrustErosion = 2
const FractionalTrust_Gain_fromInternalWork = 0.2
const IndicatedRate_toGain_TransparencyPTDI = 1

```

const IndicatedRate\_toGain\_TransparencySME = 1  
 const Initial\_KnowledgePTDI = 0.8  
 const Initial\_KnowledgeSME = 0.8  
 const Initial\_TrustPTDI = 0.8  
 const Initial\_TrustSME = 0.8  
 const Normal\_Effectiveness = 1  
 const Normal\_Fractionaltime\_forTrust\_Erosion = 1/0.1625  
 const Normal\_GainPTDI = 1  
 const Normal\_GainSME = 1  
 const Normal\_kn = 1  
 const Normal\_KnowGain\_perTask = 1  
 const Normal\_knowledge\_creation\_inCollaboration = 1  
 const Normal\_KnowLevel = 1  
 const Normal\_Task\_Rate = 1  
 const NormalRate\_toAbsorb = 0.1  
 const NormalTrustGain\_throughCollaboration = 1  
 const Processing\_Rate = 3  
 const PTDItime\_forDecay = 1.2  
 const SMeTime\_forDecay = 1.2  
 const Start\_time\_for\_Assistances = 3  
 const Time\_toDecay = 1.2

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