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Original Article

Application of Systems Thinking for Innovation Using Conventional Tools

Dr. Julia Taylor

Director, Taylor Success Systems

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Abstract: *Implementing the use of systems thinking for innovation in organizations, especially large established organizations, is difficult. Too often efforts at implementation end up being too linear and limited in scope and do not really take advantage of systems thinking. This paper describes a theoretical process that attempts to embed systems thinking, so that broader scopes of considerations are included. It uses causal mapping and network analysis to zero in on specific details without losing sight of the big picture. Several key issues are important: 1) considering the impact on established business endeavors, 2) timing of steps and investment in new innovative endeavors, 3) methods and level of involvement of key players, as the work evolves, in the new innovation. This paper will offer interested parties a new concept for developing their own in-house framework for using systems thinking to bring in novel innovation.*

Keywords: *Systematic Thinking, Conventional Tools, Theoretical Process, Embedded System Thinking.*

I. INTRODUCTION

There are a number of tools, processes and software programs available that might be useful for getting a new technological innovation going in a company. They will probably need to be adapted to incorporate a systems thinking approach. New innovation requires a systems thinking approach because it will upend the old technology and it can only be implemented if the whole company cooperates with the initiative, or in some cases the cross section of the company that is affected by the change.

Using tools for Systems Thinking is challenging because the universe of variables encompassed must be reduced to a reasonable number. The reason is because too much detail will obscure the model and render it meaningless. Models only have meaning for a particular purpose. They do not contain all possible information. A model is not reality, it is a representation of reality that can be useful. It is important to be aware that a model can often be improved by creating iterative versions of it.

There is a tendency to try to simplify complex situations in order to grasp them. This means that using Systems Thinking has to be a deliberate effort, because it goes against the typical inertia that exists.

What kind of theoretical process will actually embed systems thinking? It must first clearly identify assumptions. You will have assumptions because using assumptions allows you to create a model. Knowing what they are explicitly is useful, because if you are aware of them you can change them.

If it cannot be a truly non-linear model, then it must account for non-linear elements. Some elements bear more significance than others. Those should be assigned a higher weight in the model. There may be delays that impede the flow of the model, those should be identified. Any other time effects should be identified, and designated in such a way that it makes sense for the model-- in terms of speed. Finally, some small elements might have a disproportionate impact (exponential impact) on the overall outcome. This goes beyond having a higher weight, it means that there's a tipping point for the model.

If paying attention to assumptions and incorporating the above mentioned elements is done, then conventional tools can be useful for the process of launching a new innovation within a corporation. These tools have to be tweaked a bit, but with a few alterations, they can be instrumental in bringing about the desired change.

First, this paper will emphasize that individuals who participate in model building must have an awareness of systems thinking and the power of these principles. After that, I will briefly review a number of existing tools/ processes that might be possible to adjust, for use with innovation challenges. A few of them will be discussed, along with how they might be used, including examples to illustrate (at least theoretically) what a model might look like that used modified conventional tools.

For this paper, the process of globally screening and selecting potential new innovation is not addressed. The focus here is on the process of getting an identified innovation implemented or cancelled as a company wide, system wide new innovation.

Those who do model building or mapping need to be able to apply Systems Thinking principles for these processes. One way to achieve this might be to screen participants according to their systems thinking capabilities. Screening might be done using an instrument or through interviews conducted by a competent interviewer.

Arnold and Wade from Stevens Institute of Technology (2017) have identified Systems Thinking skills for important aspects of how they approach the system: Mindset, Content, Structure and Behavior. They identified a number of criteria for each of the four aspects. Each of these has five possible ratings. The ratings tell you the level of skill that the individual has, which will be somewhere between low and high. The four aspects and their skill criteria are shown in the next visual.

II. METHODOLOGY

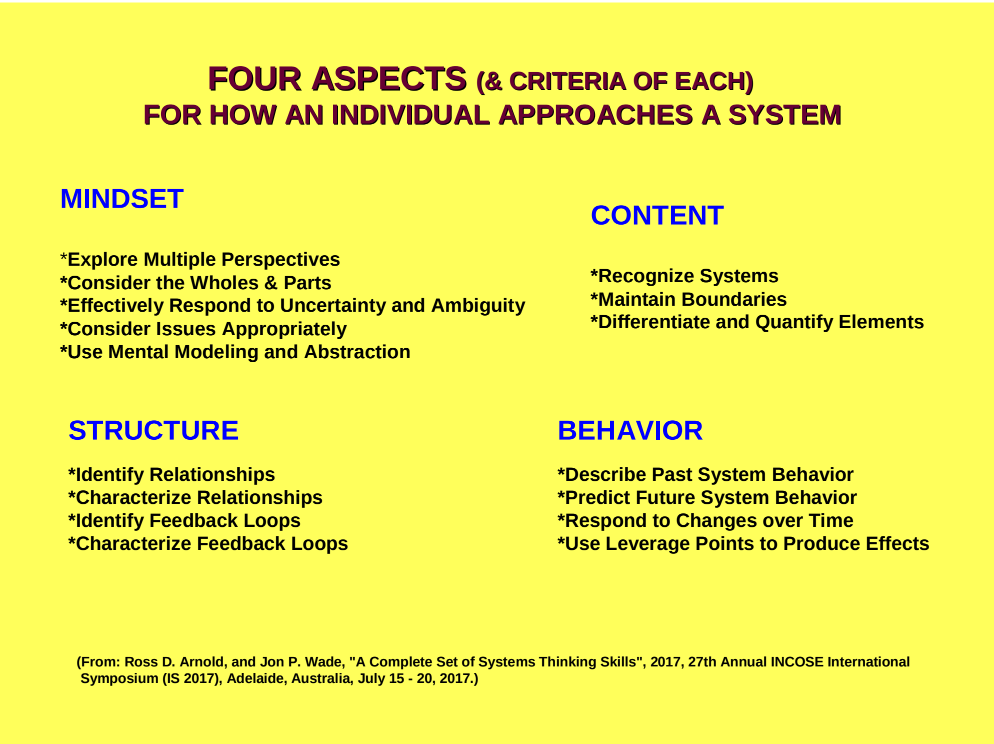


Figure 1: Four Aspects

Mindset includes the criteria of: how a person views a system in terms of perspectives. They created a five point scale where the lowest rating on the scale is: "Approaches a system from only one perspective." The second rating on the scale is "Explores other familiar perspectives when approaching a system." The third rating on the scale is "Begins to explore unfamiliar or contentious perspectives." The fourth rating on the scale is "Actively explores unfamiliar perspectives, but still tends to miss some non-obvious perspectives. Finally, the fifth rating on the scale is "Actively explores multiple, non-obvious perspectives, some of which might conflict with the thinker's view." These ratings distinguish between the level of skill that an individual has on the criteria of perspective taking, which is an important element of Mindset. (Arnold and Wade)

Possibly these skill criteria could be evaluated using a 360 degrees type of feedback evaluation for each potential participant that is screened. 360 degrees instrumentation is done by colleagues, supervisors, management and self-evaluation by the individual. That way a clear picture of an individual's System Thinking skills could be identified.

Some of the ratings Arnold and Wade have identified could probably be used as they are, while others need to be explained in language that is clearer to the non-researcher. Using an instrument means that the individual using it must be able to understand the questions. With an instrument, no one is there to explain what each question means or answer questions about what is being asked. Therefore, it has to stand on its own.

If an interview approach was used, the interviewer would be able to check with the individual and make sure the person understands what is being asked and can relate the question to his or her own situation.

It might be necessary to incorporate some education and training for Systems Thinking. This would be bound to improve the skill level of participants. However, it would be time consuming and costly. Plus people new to the ideas might not necessarily be able to adopt them right away. Even if they know and understand Systems Thinking, they might not choose to use Systems Thinking. This could be because of ingrained habits and resistance to change.

That is why it seems that if possible, it would be better to find people, with the right functional skill sets, who already have Systems Thinking skills. These would be the best people to select to participate in model building and mapping events.

It is important to grasp the big picture. In order to diagnose whether or not the overall big picture is changing towards the new innovation, network analysis is useful. Network analysis takes advantage of computer technology in order to map out, for example, what the actual lines of communication are --in an organization.

One study was quite interesting because it involved a rather large pharmaceutical company that took pride in having a flat organizational structure. Employees communicated with whomever they wanted, spending a lot of time consulting with people in the organization regarding key decisions. There were conflicting goals across functions. Seventy-five percent of employees said they spent more than half of their time in meetings that did not have an agenda and usually did not result in action. Network analysis revealed that each decision involved too many people and too much communication.

Employees had believed that their company had very little hierarchy. Then they conducted network analysis. The following visual shows what they discovered.

It turned out that the company had become highly dependent upon hierarchy. For example, one decision for a $39,000 purchase took two months and cost them $17,000 in labor costs. Company leaders had become unintentional decision blockers for employees at all levels. The red dots that you see represent Vice President or higher positions at the company. The analysis shows that these people did block effective decision making. (Cross, Thomas, et al)

Network analysis allowed executives to see blind spots that were preventing them from identifying and discussing important problems. What really matters in an organization is how the work actually gets done, not some imaginary "formal" depiction of it.

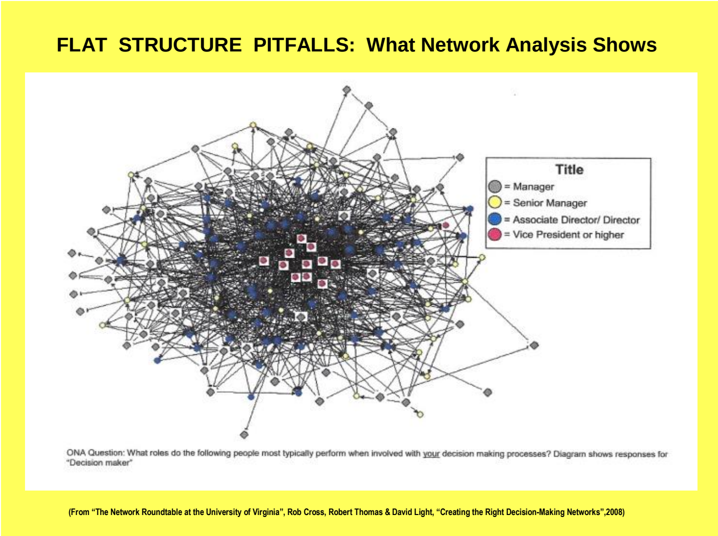


Figure 2: Flat Structure Pit Falls

For new innovation projects, it is more likely that the problem will be about "not enough" communication, rather than "too much". Both situations are problematic, but whereas too much communication can slow things down, not enough communication, when it comes to introducing new innovation, can mean that it does not happen at all.

The visual below shows a situation where the company needs a lot more cross-functional teamwork than is possible with the current network architecture.

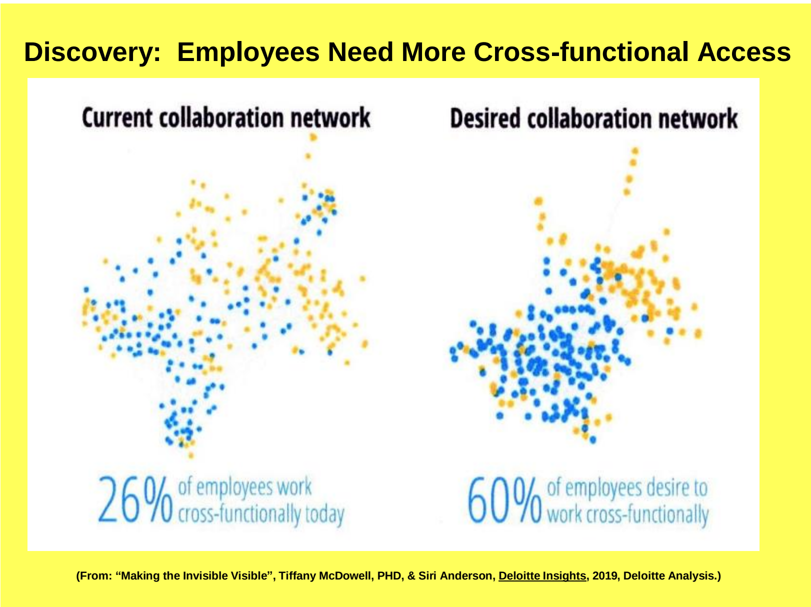


Figure 3: Discovery: Employees Need More Cross-Functional Access

Cross-functional cooperation is vitally important when it comes to new innovation projects. This visual shows how people need to be connected in order to get their goals met. This was revealed through network analysis. This visual is a good illustration because it is easy to see the difference between "what the situation is now" and "what the situation should be". Now the company has the opportunity to change the network architecture so that it will work effectively.

A fortune 500 company had an innovation team that wanted to scale their innovation into the core of the company. Before trying to integrate into the rest of the company, they were very successful. Then when they tried to get the rest of the company to start to incorporate the new innovation, it did not work very well. Using network analysis the company found that the innovation team and other functions had been stalled in silos and were not really integrating together at all.

(McDowell and Anderson) Network analysis can be a very useful tool for determining how the communication is going within an organization.

Several key points are important to keep in mind when thinking about using network analysis. First, this is a tool which can show what is happening, but it does not prescribe what should be happening. That will depend upon what needs to happen in each specific situation. Second, situations and projects that take place in organizations are dynamic. This means that you can't just figure out a useful pattern and assume that it will always work. Certain patterns work at certain stages and in particular situations.

Before you become concerned about whether change is working or not, you will need to understand the situation and orchestrate activities so that the new goals can be properly addressed. For this, you will need additional tools.

Here's a visual that shows a number of approaches/ processes/ tools that can be used to deal with multiple variables and complex situations. Some of these methods are qualitative, while others are quantitative.

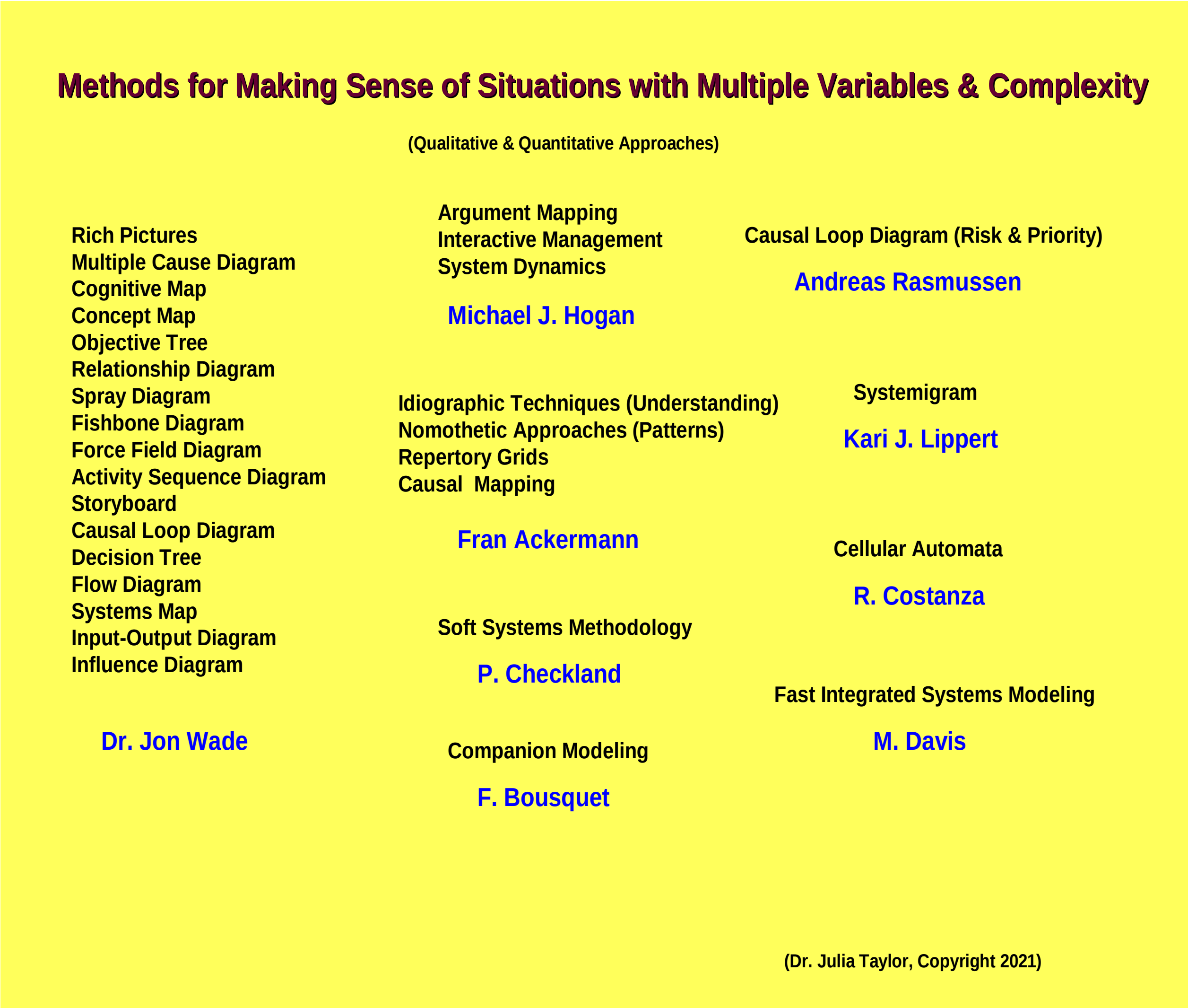


Figure 4: Methods for Making Sense

There are also a number of software programs that can be used to facilitate these processes. The following visual shows some of these.

Three of these methods caught my attention as being potentially useful for application to innovation. Although some researchers view these methods as taking into account Systems Thinking, I think they need to do this better. My concerns have to do with problems inherent in having a map or model on the medium of a flat piece of paper, which seems like could lean towards a static or linear interpretation. The problem with a linear view is that it can loose a lot of detail, some of which might be very important to consider.

With all of the new technology that is becoming available such as AI, machine learning, and digital twin technologies perhaps a 3 dimensional, moving medium might work better. However, it is also worth considering that for complex situations, what you need is a way to get a handle on them. In order for us, as humans, to comprehend them, a way to simplify them is often helpful. A flat 2 dimensional representation is much simpler than a 3 dimensional moving system. Therefore, initially, when a lot is uncertain and unknown, it might be better to use the 2 dimensional representation as a starting point.

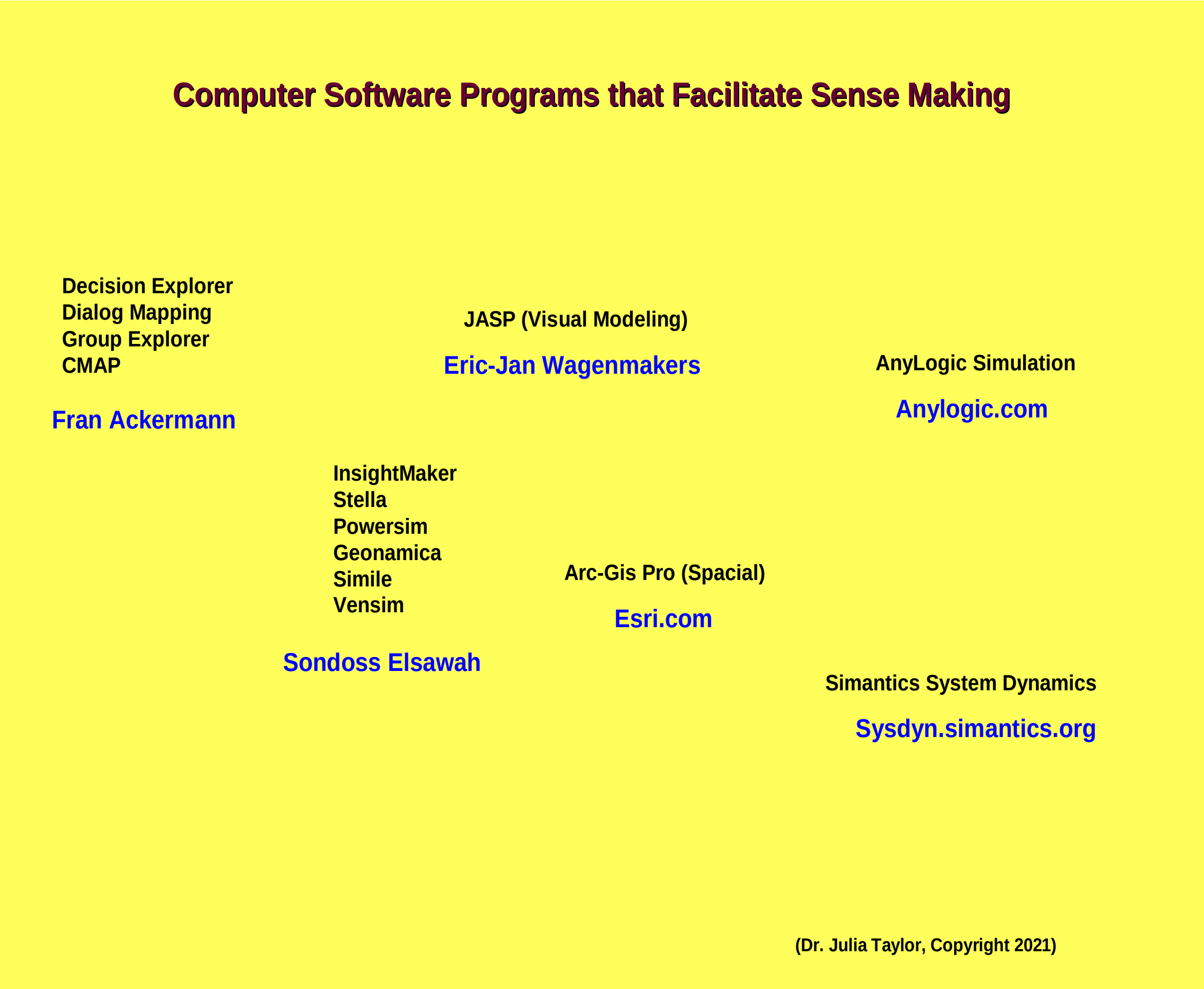
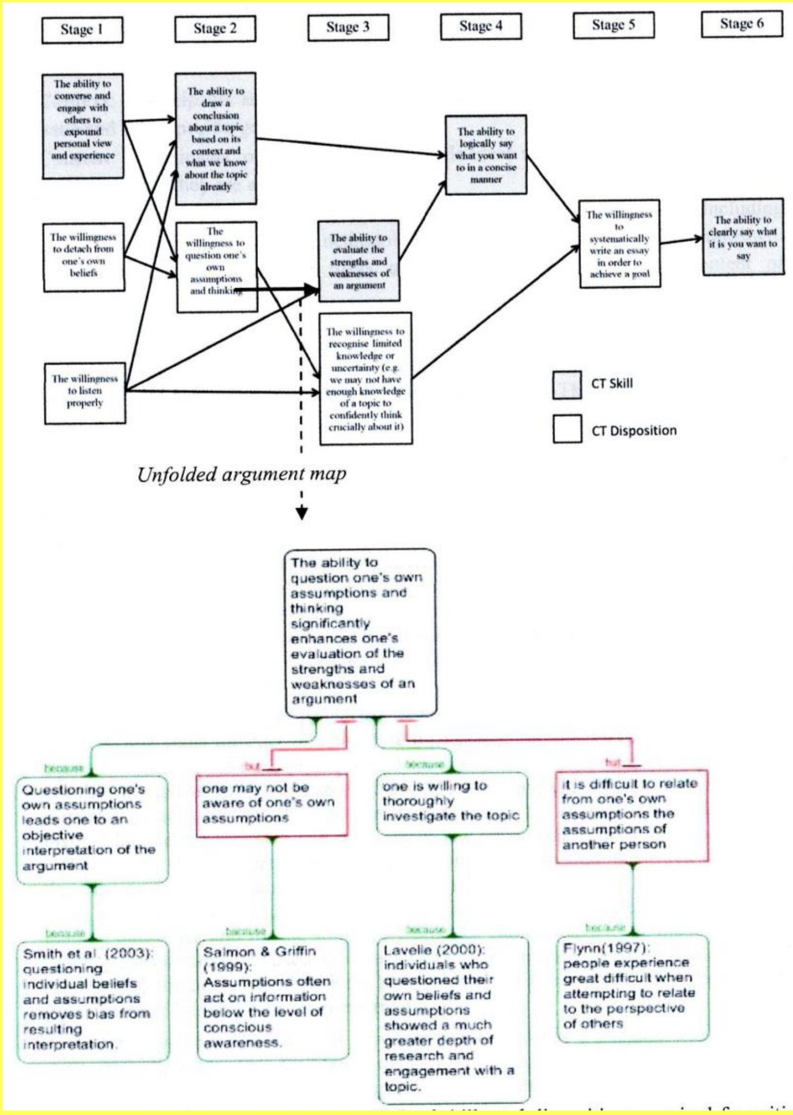


Figure 5: Computer Software Programs

The three methods that appealed to me are: 1) Interactive Management combined with Argument Mapping, 2) Fuzzy Cognitive Maps, and 3) Causal Mapping. Interactive Management with Argument Mapping is useful because it helps with critical thinking. (See the next visual.)

Interactive Management Example with Argument Map Showing Rationale



(From: Michael J. Hogan, Owen M. Harney, and Benjamin J. Broome, "Integrating Argument Mapping with Systems Thinking Tools– Advancing Applied Systems Science", "Integrating Argument Mapping with Systems Thinking Tools-- Advancing Applied Systems Science", 2014., p. 9).

Figure 6: Interactive Management

Interactive Management is a computer facilitated mapping technique that helps groups develop results that integrate contributions from participants who are from different disciplines and/or have different perspectives and views. Argument Mapping is about evaluating what "you think you know" at each stage of a process. The benefit is that by unearthing what is behind what you think, the true value of that thought or belief can then be exposed. If it is found not to be useful, then at that point, it can be changed.

Next you see the key product of the Interactive Management process, which is this visual diagram showing their key issues and how they are related.

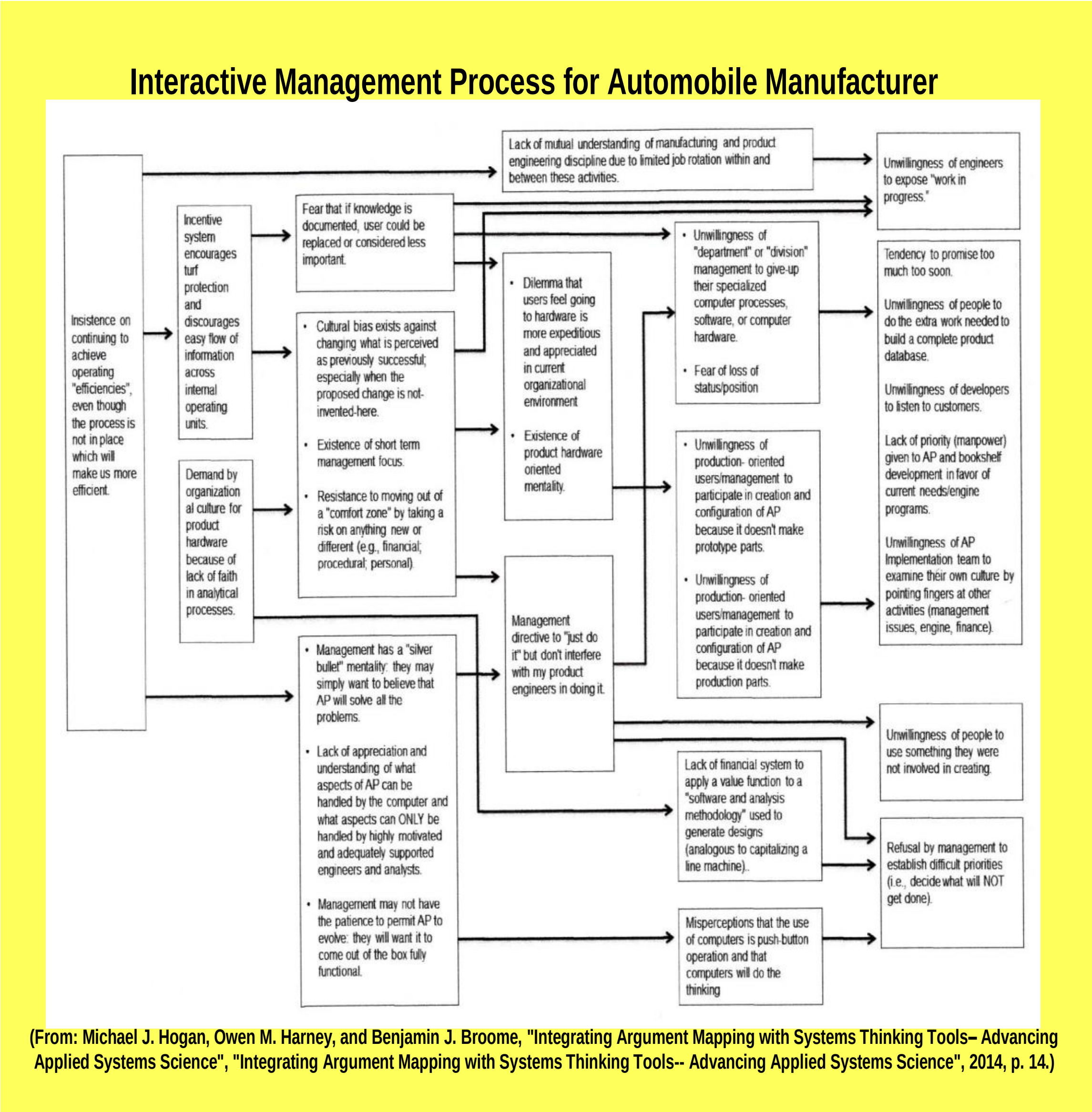


Figure 7: Interactive Management Process for Automobile Manufacturer

This was produced by a car manufacturer that was trying to integrate hardware and software into a system that would allow sharing design and manufacturing information among multiple departments. This process was not going well, so it had to be addressed.

The Interactive Management exercise allowed the problems to emerge so they could be seen and identified. The relationships of the problems are also shown. These were important because- only by understanding the way they were connected, was it possible to identify an underlying cause.

The cause turned out to be a culture that did not support what the new technology was trying to do. The solution was to use this new information to help them generate options to address the problem. They were able to generate over 200 possible options that could help them to create a more conducive organizational environment. They were then able to select some options, based soundly on their IM process, that could be implemented, and ultimately turn the situation around. (Hogan, Harney, et al)

I like this process because it allows the "symptoms" to be viewed in a new light. Viewed independently, they do not appear to be solvable. Probably they are not solvable as discrete problems, because they were created because of the connections inherent in various activities. Viewed as a whole, then looking deeper into "what's behind them", revealed a path forward that could be actualized through many different possible responses.

The kind of innovation that I am concerned with is when a company produces a new product that is possible because it has new innovation incorporated into it. Even though this example is not about that, still the change required by this organization in order to implement their new technology system, could be very similar to what happens when a product utilizing new technology is being produced by a company. IM and AM could serve as useful tools to help make it happen.

The second interesting method is Fuzzy Cognitive Maps. This method combines fuzzy logic with cognitive mapping. The example below, which is about Deforestation of the Brazilian Amazon, shows this process.

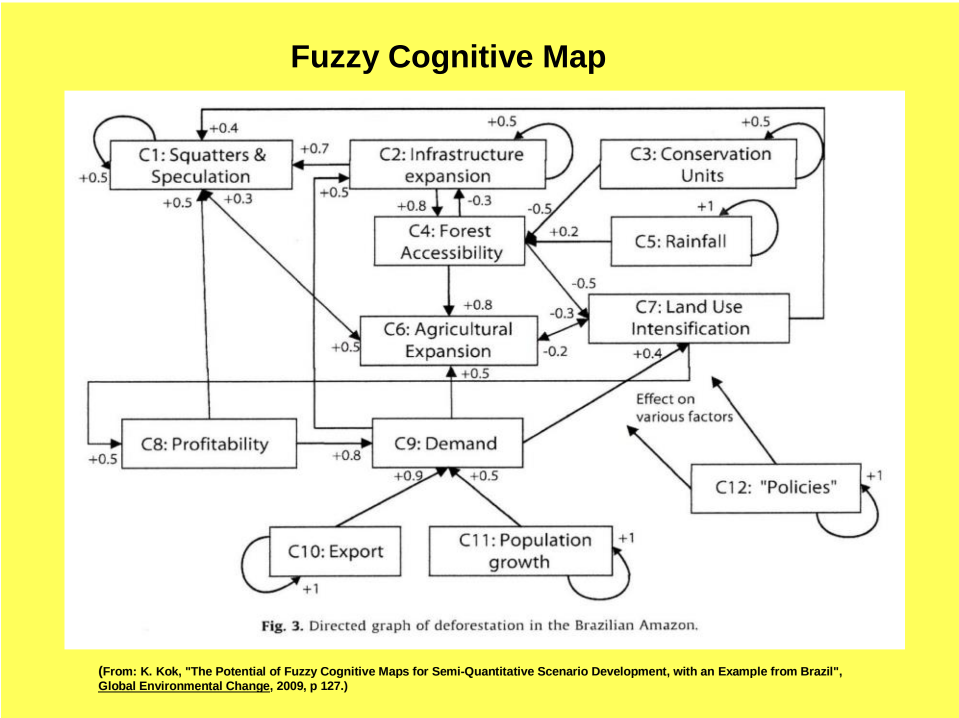


Figure 8: Fuzzy Cognitive Map

Fuzzy logic is an approach to computing based on "degrees of truth" rather than "true or false"(1 or 0). Fuzzy logic works on the principle of assigning a particular output depending on the probability of the state of the input. Cognitive mapping is a mapping method used to create a visual representation of a group's mental model for a process or concept. It can be used to identify patterns. Fuzzy Cognitive Maps map the elements of a system in nodes and provides a relationship between the nodes in terms of direction and strength. (Elsawah, Pierce, et al)

Fuzzy Cognitive Maps result in calculations that quantify elements in order to show meaning that wasn't evident before. I like the features of direction and strength that are incorporated into this method. Strength implies that different relationships have different weights. With this capability, a clearer picture of what is happening can emerge. With careful planning and adaptation, this method might be applicable to innovation implementation challenges.

It is important to note that some researchers believe that mathematical and computer computation (quantitative analysis) add credibility to sense making processes, while others believe that it can even be counterproductive. It may depend a great deal upon the degree of uncertainty and ambiguity of a particular situation. Getting too overly quantitative too soon might obscure one's vision regarding the overall picture. On the other hand, it might be possible to clarify certain questions and therefore reduce some of the initial ambiguity. Overall, I would say that tools need to be used carefully and thoughtfully.

The third interesting method is Causal Mapping. Causal Mapping makes use of nodes for important elements of the system, plus lines that link the nodes together in a particular direction and indicate the relationships between the nodes. The links between the nodes represent causality or influence. I like this method because it allows a group to quickly identify the links between key elements such as actions and key characteristics of a system. See example below.

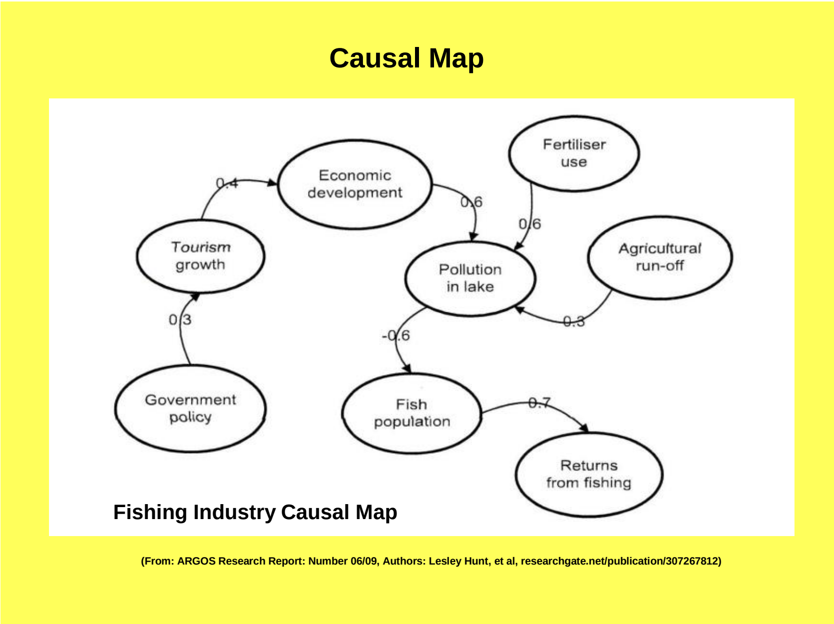


Figure 9: Casual Map

Perhaps it might be possible to adjust and modify each of these three methods to serve the challenge of introducing and implementing new innovation for a company. Next I will explore the notion of applying Causal Maps for this purpose. I am calling my adaptation of this method Innomap. The visual below shows key guidelines for this method.

INNOMAP Key Elements and Relationships

1) Include **Nodes** (Elements) for each classification of employees involved. [For example: Upper Management, Management, Research & Development, Marketing, Production, Product Teams]

2) Include **Nodes** for each type of activity, relevant established business endeavors, and new innovation investments.

3) Using **lines** (to show links) show how the nodes are related to each other.

4) Make note of the key **assumptions** behind the links and key assumptions that affect the map.

5) Determine which links should be more heavily **weighted** than others, and by how much each should be weighted.

6) Use a **separate map** for each phase to show the changes over time.

7) Indicate where there are any **pivot points** or leverage points where a small event has a disproportionate impact on the overall system.

(Dr. Julia Taylor, Copyright 2021)

Figure 10: Innopmap Key Elements

Using this mapping technique (Innomap) which consists of key elements (nodes) and relationships (lines), include nodes for each type of employees involved (upper management, management, research & development, marketing, production, project team, etc..), each type of activity involved, relevant established business endeavors, and new innovation investments. Using lines show how these nodes are related to each other. Make note of assumptions that could impact the mapping process. Determine which links (lines) should be more heavily weighted than others, and by how much (subjective decision). In order to capture the essence of change over time, use a separate map for each phase. The number of phases needed will depend on your judgment, but it will probably consist of at least four: the beginning, the main integration phase, the design refinement and production initiation phase, and full scale production. Finally, there will be at least one major pivot point where a small event or activity will have a disproportionate impact on the overall system. Designate where these leverage points are on your map.

Now I will give you a hypothetical example of using this method. One of the guidelines has to do with identifying assumptions. Next I will review some of the assumptions that apply for this example.

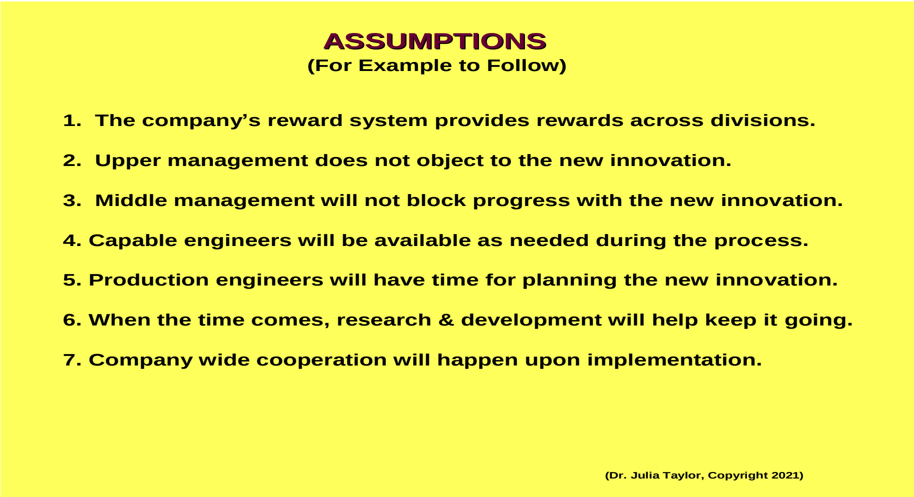


Figure 11: Assumption

In the beginning, the innovation team works on the project and is mostly separated from the rest of the organization. This is depicted next is the Main Integration Phase. This is where most of the activity to launch the new innovation takes place. There is usually a financial investment that is outside the norm of day-to-day operations, that is applied towards the new innovation. There is a flurry of new communication and preparation between various functions and departments that must happen in order for the new product (based on the new innovation) to materialize.

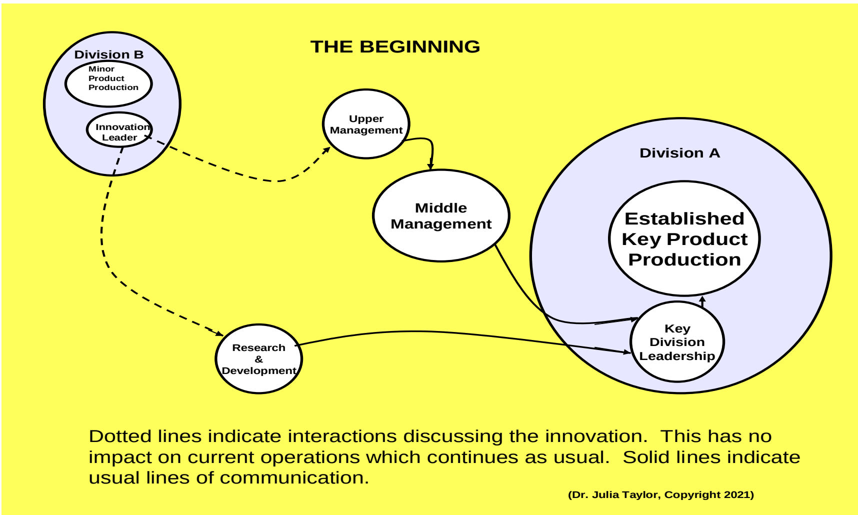


Figure 12: The Beginning

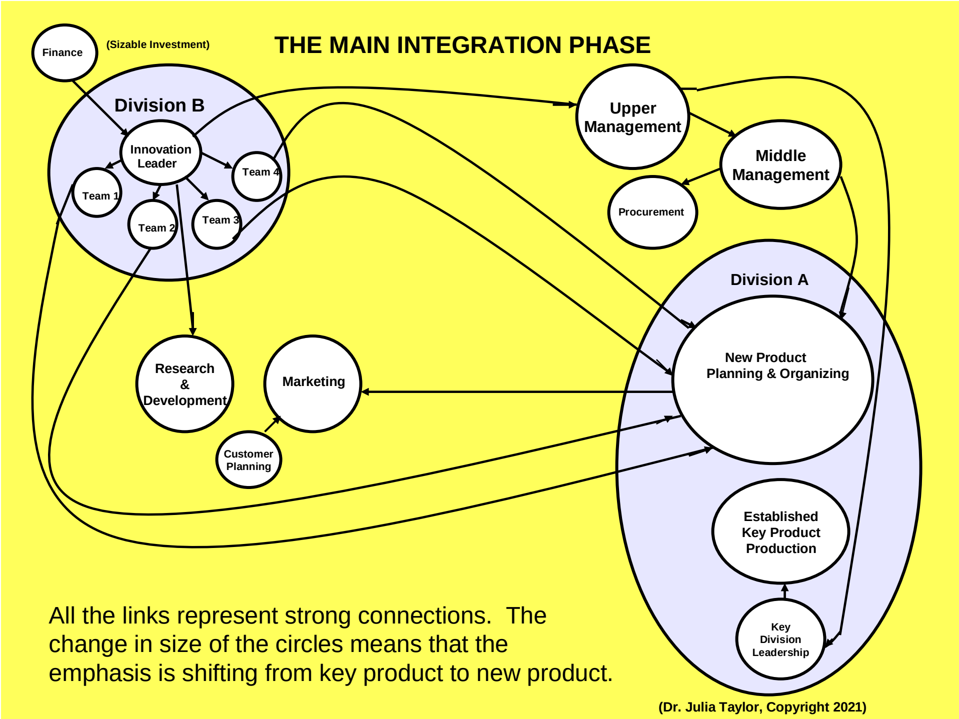


Figure 13: The Main Integration Phase

The next phase is the "Design Refinement and Production Initiation Phase". This is the phase where the biggest go or no-go decision is made. If the company decides to move forward with the new innovation product at this point, then a sizable investment will have to be made as well as commitment of resources including personnel and capacity. All necessary departments and functions must be on board and prepared to embrace the new innovation full steam ahead. Any remaining bugs or problems with the new innovation have to be ironed out at this stage.

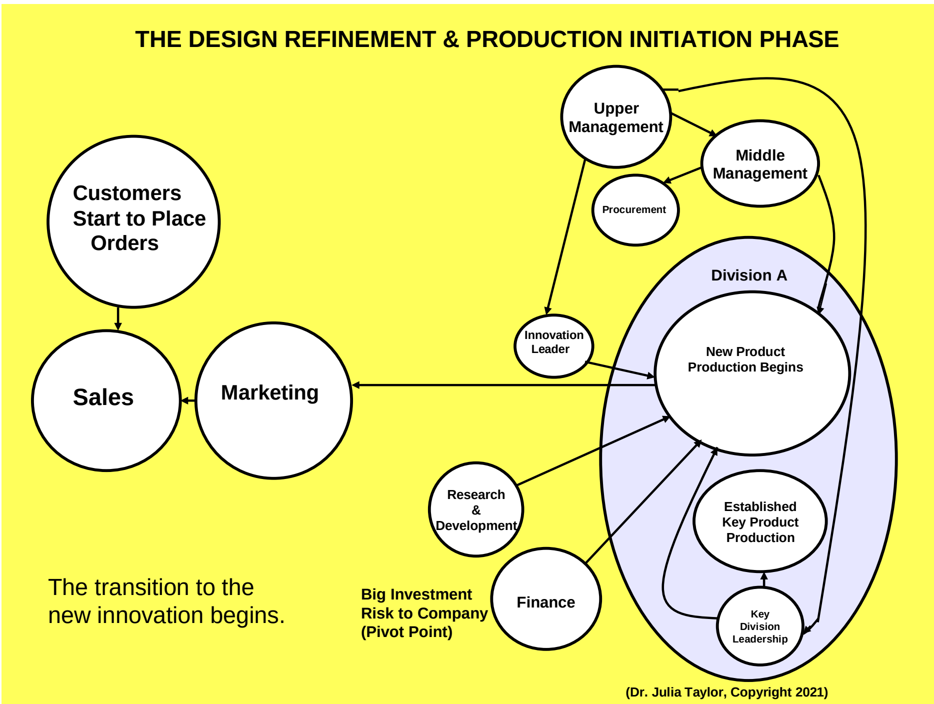


Figure 14: The Design Refinement & Production Initiation Phase

Finally, the last stage is the production phase. (See below)

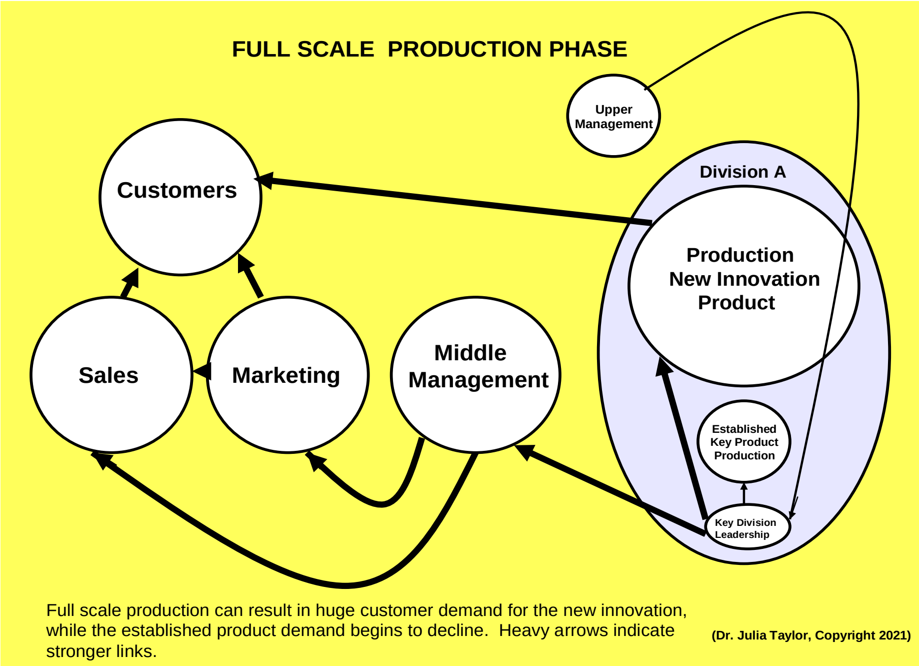


Figure 15: Full Scale Production Phase

This stage can be problematic if unanticipated issues arise. They have to be resolved fast. Hopefully, there won't be any hesitation to deal with them now because the company is fully committed to the new innovation product. Connections within the organization become a lot stronger, while interactions with upper management become a lot less frequent and a lot less intense than during the first three stages. There is a lot of attention devoted to customers from various departments to make sure the new innovation product is delivering the expected results.

Network analysis can provide insight into whether or not Phase 2, the main integration phase, is underway in reality. It will show whether or not there is communication flowing toward the manifestation of the new product introduction. This is critically important for success. (See visual that follows.) Red arrows indicate areas where you should see increased communication.

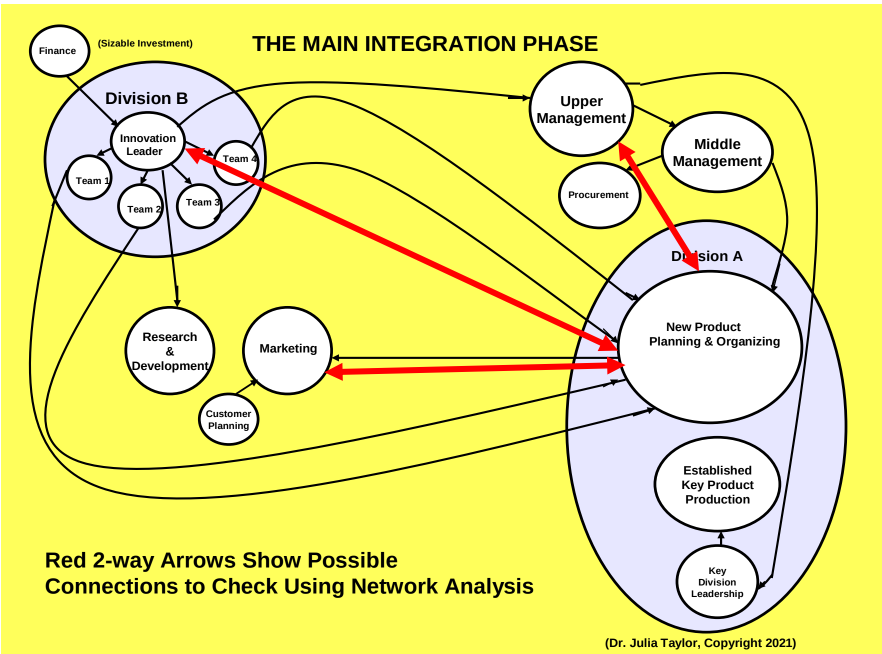


Figure 16: The Main Integration Phase

It might also be useful for Phase 3, the design refinement and production initiation phase, but not as critical as for Phase 2. (See visual that follows.) The red arrows show some areas where communication should be flowing if this phase is actually being implemented.

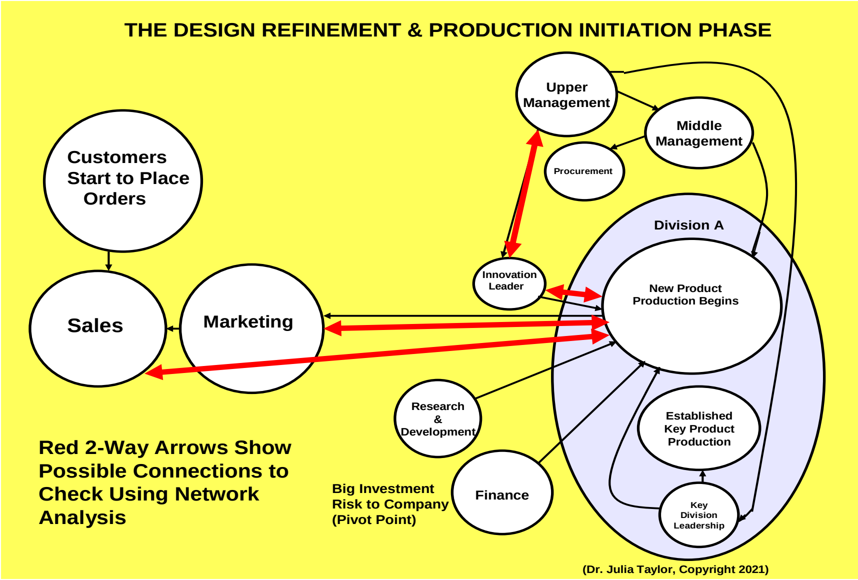


Figure 17: The Design Refinement and Production Initiation Phase

The impact of innovation can mean that established business endeavors end. People in the organization for whom the established business has been the source of their livelihood, can feel very threatened at the prospects of a new product. That is why it is very important that there is a person who is championing the new innovation. It is also crucial that upper management supports the champion and paves the way for them to initiate the change needed to move forward. There is usually a lot of inertia in organizations and therefore a big tendency for the organization to favor the established business. It is very difficult to overcome this inertia and get the ball rolling for new innovation.

At the same time, the major profit producing business must be allowed to continue as usual until the new innovation is ready to roll out. The first stages, in my example the first three stages, have as their key product the old established product. During all this time the new innovation is not being produced, but massive work is being done to make production possible. Therefore, the old product is providing the financial gains for the company, not the new innovation. The two must coexist for a certain period of time. This might be a bit awkward, but it is necessary. The "timing of the steps" of the process of getting a new innovation going is important. The Main Integration Phase should not be started before there is genuine progress in the Beginning Phase. This might take longer than is expected. There is no set time limit.

Once people in the company are prepared to bring in the new innovation, progress might proceed faster than expected. Although there is a lot to be done in the Main Integration Phase, it could happen quite rapidly. Investment in the new innovation can accelerate progress. This often starts in the Main Integration Phase, but the biggest investment probably occurs at the Design Refinement and Production Initiation Phase. However, keep in mind that what makes sense depends on the industry and the specific details that control how that industry operates.

Note that more key players get involved and involvement becomes more intense as the stages progress from stage 1 to stage 4. Since people have different functions, everyone is not concerned about the same issues. Methods for working together depend upon the goals at each particular stage. People need to be flexible and able to adapt to the changing situation as the new innovation is evolving. Conventional Tools can be modified to incorporate Systems Thinking principles that apply for the process of introducing new innovation products into an organization. An approach can be designed, a framework, that will apply for each specific situation.

First, selecting individuals to participate in this process is important. The goal is to select people with Systems Thinking skills. Arnold and Wade have identified essential Systems Thinking skills which can be used for this selection process.

Second, there are a number of existing tools, processes and computer programs that potentially can be adapted to address challenges that companies face when implementing new innovation products. An overview of these was presented to offer possibilities for tools that can be used or might be effectively used for this purpose.

Third, three of these methods were reviewed along with presenting highlights of their advantages for innovation projects. They were Interactive Management combined with Argument Mapping, Fuzzy Cognitive Maps, and Causal Mapping.

It was also suggested that Network Analysis might be used to verify whether or not the process of implementing a new innovation was actually underway or not. Examples of Network Analysis were presented. The Causal Mapping method was adapted by the author using a set of guidelines to create a method called Innomap. A hypothetical example of Innomap was presented.

Companies can use the concept of Innomap to create their own framework for guiding the innovation implementation process. This offers help for addressing the current business while pursuing the new innovation. It helps to clarify the timing of the steps as well as the level of involvement of key players as the implementation process progresses. Finally, it highlights the timing and corresponding level of investment that it takes to launch a new innovation.

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