DOI NUMBER: 10.19255/JMPM01203

KEYWORDS › Project planning › Risk › Uncertainty › Agility

HANDLING RISK and UNCERTAINTY IN PROJECT PLANNING

Jan Emblemsvåg

Norwegian University of Science and Technology

emblemsvag@yahoo.com

ABSTRACT

There are basically three avenues for dealing with risk and uncertainty in project planning as – 1) forecast its impact before making a decision, 2) maneuver or adapt to uncertainty and risks that materializes and thus making it irrelevant, or 3) accept it. To discuss this the very definitions of uncertainty and risk are revisited because there is great confusion about uncertainty and its cousin risk – also in the literature. Once a proper distinction between these two concepts are established, the paper will show that if project planning is contemplated as 'planning for coordination' we can augment it with agility to handle surprises, which is in contradistinction with the 'planning the future' approach which is path dependent and fails to handle surprises.

1. Frame of Reference

Uncertainty is prevalent in everything we do so understanding how to deal with it is of utmost importance – also in project planning. When we take into account that planning is crucial in the success of projects (Laufer and Tucker 1987, 1988; Oehmen 2012; Powner 2008), it follows that dealing with uncertainty in planning is important. Nonetheless, few commercially available planning tools have proper functionality for handling uncertainty. Why? This is probably due to the fact that realistic handling of uncertainty leads to quite advanced methods such as Monte Carlo methods, see (Emblemsvåg 2003), and that this is perceived as too difficult to include in the tools. A second issue is that many uncertainties in projects are hard to include in planning irrespective of tools and methods such as the quality of technical documentation received in an engineering activity, possible mistakes and subsequent rework, technical failures of equipment leading to waiting time and so on.

Before continuing, I would like to highlight that when the term 'project planning' is used in this paper, it refers to making- and following-up schedules, see (Kerzner 2013). This clarification is crucial to distinguish it from the broader concept of making project plans which is essentially project management. The initial claims of the three avenues of dealing with uncertainty and risk must be seen in this light and for the remainder of the paper as well.

With this in mind it becomes natural to ask how uncertainty should be handled in project planning in general, which is the topic in this paper. This leads quickly into the concept of risk as well. While there is consensus on the importance of handling uncertainty in projects, the agreement soon breaks down when project planning methods are held up against risk management methods. There is little, if any, resemblance. Project planning literature discusses uncertainty and risk only cursorily while risk management literature typically ignores project planning altogether, and in most of the literature the distinction between uncertainty and risk is poorly handled. This state of affair is damaging to the important field of project management – for which project planning is an integral part (PMI 2008) – and this paper therefore want to address this in an attempt to primarily add insight as to how uncertainty and risk should be addressed in project planning conceptually speaking.

Before proceeding, a discussion on risk and uncertainty is therefore warranted so we know what we are talking about. A full discussion on risk and uncertainty is provided in (Emblemsvåg 2015) to which the interested reader is referred to. Then, the concepts of planning are discussed in Section 3.0, before the crucial discussion on maneuverability in Section 4.0. Then, in Section 5.0, it is tied together in an improved approach to project planning. A note on Agile methods is found in Section 6.0 to discuss the differences since Agile methods have not been explicitly discussed, before the paper s closed off in Section 7.0.

2. On Risk and Uncertainty

The word 'risk' derives from the early Italian word risicare, which originally means 'to dare'. In this sense risk is a choice rather than a fate (Bernstein 1996). Other definitions also imply a choice aspect. Risk as a general noun is defined as 'exposure to the chance of injury or loss; a hazard or dangerous chance' (Webster 1989). Along the same token, in statistical decision theory risk is defined as 'the expected value of a loss function', see for example (Hines and Montgomery 1990). Thus, various definitions of risk imply that we expose ourselves to risk by choice, which also includes not choosing or making a decision.

Uncertainty, however, as a general noun is defined by as 'the state of being uncertain; doubt; hesitancy' (Webster 1989). Uncertainty comes into play because 'the source of risk is uncertainty' (Peters 1999), but unlike risk there is neither loss nor gain necessarily associated with uncertainty. It is simply the not known with certainty.

When it comes to measurement, risk is commonly measured in terms of 'consequences and likelihood' where likelihood is understood as a 'qualitative description of probability or frequency', but frequency theory is dependent on probability theory (Honderich 1995). Thus, risk is a probabilistic phenomenon as it is defined in most of the literature. Note that risk is not consequences multiplied by likelihood. This is because multiplication implies a risk neutral decision-maker as pointed out by (Hubbard 2009). This insight again emphasizes the choice/decision aspect of risk. Thus, it is important to distinguish between the concept of probability, measures of probability and probability theory. Unfortunately, this is rarely done properly. Consequently there is much dispute about the subject matter of probability (Honderich 1995). From its linguistic roots, probability can best be defined as a 'degree of belief', but it is vital to understand that it can be measured in several ways out of which the classical probability calculus is the best known. For simplicity and generality, the definition of risk found in Webster serves the best for this paper – the 'exposure to the chance of injury or loss; a hazard or dangerous chance' – while risk is measured in terms of 'degree of impact and degree of belief'. Finally, it is important to emphasize that 'risk is not just bad things happening, but also good things not happening' (Jones and Sutherland 1999).

When it comes to uncertainty, some define it as 'the inability to assign probability to outcomes', and risk is regarded as the 'ability to assign such probabilities based on differing perceptions of the existence of orderly relationships or patterns' (Gilford, Bobbitt et al. 1979). However, such definitions are too simplistic for a number of reasons. For example, it provides no insight into uncertainty at all – it is merely what we cannot assign probabilities. Furthermore, it treats risk and uncertainty as the same phenomenon except one is less known that the other. However, an important realization from years of study is that uncertainty and complexity are intertwined and as an unpleasant side effect, imprecision emerges. Lotfi A. Zadeh formulated this fact in a theorem called the Law of Incompatibility (McNeill and Freiberger 1993):

> As complexity rises, precise statements lose meaning and meaningful statements lose precision.

Since we all experience some degree of complexity, this theorem is crucial to understand. With complexity we refer to the state in which the cause-and-effect relationships are loose, for example, operating a sailboat. A mechanical clock, however, in which the relationship between the parts is precisely defined, is complicated – not complex. From the Law of Incompatibility we understand that there are limits to how precise decision-support both can and should be (to avoid deception), due to the inherent uncertainty caused by complexity. In fact, increasing the uncertainty in decision support material to better reflect the true and inherent uncertainty will lower the actual risk as shown in (Emblemsvåg 2003).

Furthermore, (Arrow 1992) warns us that '[O]ur knowledge of the way

things work, in society or in Nature, comes trailing clouds of vagueness. Vast ills have followed a belief in certainty'. Basically, ignoring complexity and/or uncertainty is risky, and accuracy may be deceptive. Thus, striking a sound balance between meaningfulness and precision is crucial, and possessing a relatively clear understanding of uncertainty is needed since uncertainty and complexity is so closely related. Another important source for uncertainty is, of course, the future. No one can tell the future and it is from this interpretation of uncertainty that many believe that the only distinction between risk and uncertainty is that risk involved loss whereas uncertainty does not, see for example (Hubbard 2009).

The essence of word meaning is that it constitutes a generalized reflection of reality (Vygotsky 1988) and from this, and the discussion thus far, we realize that uncertainty describes the meaningfulness of information. To develop a more operational measure uncertainty we can therefore use quality as defined by (Taguchi, Chowdhury et al. 2005) whereby quality is the loss a product causes to society after being shipped, other than losses caused by its intrinsic functions. Furthermore, Taguchi asserted that there were two types of losses; 1) loss caused by variability of function, and 2) loss caused by harmful side effects. Hence, good quality means that a service, product, process or whatever "performs its intended functions without variability, and causes little loss through harmful side effects, including the cost of using it." From this, we can offer a general definition of quality – quality is a measure of the consistency of something around its target as approximately measured by the standard deviation. From this we understand that uncertainty becomes a measure of information quality, and statistically speaking uncertainty can be approximated by the famous sigma (σ) – or the standard deviation. Financial risk management performed using the famous Capital Asset Pricing Model (CAPM) is therefore not really risk management but rather uncertainty management, see (Emblemsvåg 2015) for more details. This is also fully aligned with the theory of value investing for which the world-famous investor Warren Buffet is a prominent practitioner.

Furthermore, (Klir and Yuan 1995) identify two main types of uncertainty; fuzziness and ambiguity. Fuzziness occurs whenever definite, sharp, clear or crisp distinctions are not made. Other words can be vagueness, cloudiness, haziness, unclearness, indistinctness and shapelessness. Ambiguity results from unclear definitions of the various alternatives (outcomes). These alternatives can either be in conflict with each other or they can be unspecified. The former is ambiguity resulting from discord – where we can also think of words like dissonance, incongruity, discrepancy and conflict – whereas the latter is ambiguity resulting from nonspecificity bringing words like variety, generality, diversity, equivocation and imprecision to mind. The ambiguity resulting from discord is essentially what probability theory focus on, because 'probability theory can model only situations where there are conflicting beliefs about mutually exclusive alternatives' (Klir 1991). In fact, neither fuzziness nor nonspecificity can be conceptualized by probability theories because they are based on the idea of 'equipossibility' where each outcome has an equal and 'digital' chance of occurrence. Put succinctly, uncertainty is a too wide concept for probability theory, because probability theory is closely linked to equipossibility theory (Honderich 1995). In fact, just as the majority of theories developed in the history of science and the arts ignore complexity, so does probability theory. It was simply not in their mind and a phenomenon not yet understood at that time. Therefore, uncertainty has no meaning in probability theory other than what is used in daily parlance, and this is probably one of the reasons why there is a big confusion on the topic which results in many fruitless debates.

The same problem we witness with 'probability' being a common word – which has double meaning (Bernstein 1996) – one reflecting an actual usage of classic probability theory and calculus, and one reflecting the sloppy daily usage of the word.

When we discuss measurement of risk and uncertainty we have both qualitative and quantitative approaches. There is only one language with absolute correctness and that is mathematics (Vygotsky 1988), so quantitative measures of risk and uncertainty are preferable to qualitative ones. Qualitative ones can in many cases be converted to quantitative ones by using AHP, see (Emblemsvåg 2010), so the important distinction is not quantitative versus qualitative analyses – it is between absolute and relative measures.

In the areas of probability, we have two common approaches; 1) the classic which is derived from all exhaustive and mutually exclusive set of events/options, and 2) the subjective where both of these conditions are completely relaxed. Therefore, classic probability calculus may prove deceptive in risk analyses because in most cases the two conditions are not met. This is not to say, however, that classic probability theory should be discarded altogether – in real life we just have to realize that the two conditions are often violated and admit its subjective nature, as (Kangari and Riggs 1989) state:

> … probability models suffer from two major limitations. Some models require detailed quantitative information, which is not normally available at the time of planning, and the applicability of such models to real project risk analysis is limited, because agencies participating in the project have a problem with making precise decisions. The problems are ill-defined and vague, and they thus require subjective evaluations, which classical models cannot handle.

This finding is fully in line with both the understanding and experience of this author, and it is critical for this paper because it pinpoints that challenge of forecasting under conditions of uncertainty, which is always the case in forecasting.

It should be noted that also in modern decision theory subjective probability theory is used, according to (Tversky and Kahneman 1974), where subjective probability is regarded as '…the quantified opinion of an idealized person' (Savage 2003). The derived probability is subjective in the sense that different individuals are allowed to have different probabilities for the same event. This approach therefore provides a rigorous subjective interpretation of probability that is applicable to unique events and is embedded in a general theory of rational decision (Tversky and Kahneman 1974). Thus, using subjective probabilities is no loss – it is just more realistic.

3. Concepts of Planning

There are broadly speaking two camps in project planning – those that want to forecast the future and plan it in detail for maximum effectiveness and efficiency, and those that want to create local order for effective execution without wasting time and effort on planning details in the future that we know will change anyway, see (Ballard 2000). In several industries, we see both camps represented. Later on, we will discuss this in more practical terms, but first we must explore these two major schisms of planning – 'planning the future' and 'planning for coordination'.

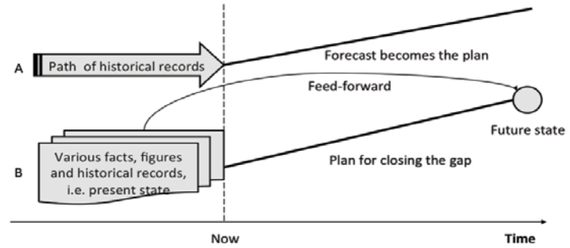

FIGURE 02. *Concepts of planning the future.*

3.1 Planning the future

Virtually all methods for planning used today are based on the belief that the future will somewhat resemble the past or depend on the past in some fashion (Allvine 1996). This is self-evident when we discuss planning based on some sort of extrapolation, regressions or any other mathematical techniques based on historical data. This leads to a path-dependent analysis as illustrated in **Figure 2** where the initial value conditions becomes vital. How we chose to forecast is, of course, a matter of mathematical choice and the initial value conditions (values at time equals 'Now' in **Figure 2**). In **Figure 2**, the easiest approach – linear modeling – is illustrated. This approach is not only the easiest from a mathematical point of view, but from my experience it is also the most common at least if we include linear derivations, i.e. constant rate of change which will produce a nicely looking upward curve.

However, regardless of how fancy we do the mathematics the path dependency and initial value choices will limit the solution space. Therefore, this approach will inevitably become predictable and incapable of handling rapid shifts of both positive as well as negative nature.

What about detailed simulation models? In this case it is not the path-dependency with respect to the numbers themselves that counts but rather the fact that the structure of the simulation model determines the outcomes almost more than the numbers, see for example (Emblemsvåg 2003). The structure, however, is predicated on the present state of the system and therefore ultimately also path dependent.

More surprisingly, the belief that the future will resemble the past to some extent is also inevitable in cases where we try to think outside the box as it were. This can be understood by considering the organo model of Karl Bühler depicted in **Figure 3**. Whatever we humans want to communicate, the communication is based on the objects we try to send/communicate about and the current state of our language, and language is a psychological tool for organizing our individual thoughts, for reasoning, planning and reviewing our actions (Habermas 2003; Vygotsky 1988). Add to that the fact that phenomenographic research shows that people typically conceive any aspect of reality in 2 – 6 different ways (Marton 1981). Basically, regardless of how creative we believe we are we will end up with a limited set of out-of-the-box descriptions that are largely predicated on the fact that our abilities to express what we have not experienced are limited. Again, we face a kind of path dependency.

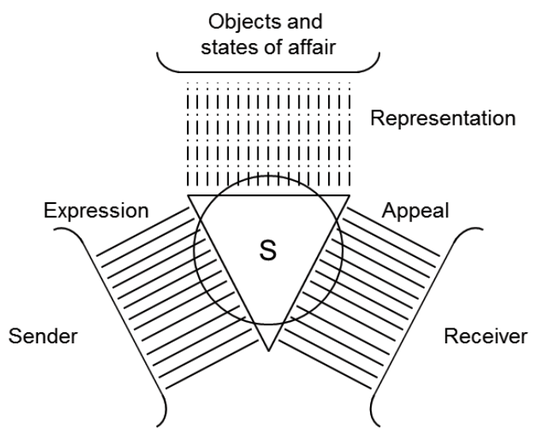

FIGURE 03. *Language Functions. Source: Karl Bühler in (Habermas 2003).*

Thinking outside the box is one thing, but a prerequisite for that is being open-minded. Unfortunately, (Nutt 1998) finds clear support for the importance of open-mindedness, but also that it is quite rare. He studied business decisions of 376 corporations over 20 years and identified four broad tactics, which in the order of common usage are:

1. Persuasion ("we've chosen this, here's why you should buy in") – was the most common tactic but it worked less than half the time, because it raises suspicion as people wonder what is not being said.
2. Issuing edicts ("do it") – was the second most common tactic but worked only in about 4 out of 10 cases.
3. Participation ("let us try to find the best solution together") – was the second least deployed tactic, but has an 8 out of 10 success rate. This is because true participation is hard to find because often it becomes a token effort, involving just a few people.
4. Intervention ("here are all the facts, let us try to find the best solution together") – was the least used approach, but it worked in 9 out of 10 cases.

The main difference between the latter two is that with intervention all facts are laid down on the table and then they try to find ways to close the gap between desired state and actual state. Focusing on the gap makes people take the problem seriously and keep the same goal and context in mind (Nutt 1998). In short, open ears, open eyes and an open mind is what it takes to implement decisions. We may believe this is common, but less than 16% of the decisions were made using the participative or the interventionist approach – almost 85% of the decisions were made in an almost manipulative way. How many of the 16% of decisions that can actually manage to take the next step and think outside the box, given the situation modeled in **Figure 2**, is hard to say but it is most likely very small and definitively not large enough to constitute a reliable basis for sustained business performance. This is perhaps why genuinely creative people are far and few in between and consequently businesses vary considerably between themselves dependent on these few people.

Nevertheless, from this discussion, a perhaps surprising conclusion can be preliminarily reached – 'planning the future' will always be a product of the past and a practically impossible approach for capturing surprises in the future. This does not invalidate project planning, however, but it does put major ramifications for project planning. Therefore, we should investigate the other approach – planning for coordination.

3.2 Planning for coordination

First of all, 'planning for coordination' seems to indicate that in 'planning the future' coordination is not important – this is not the case. Coordination is always important in project planning, but the point is that when planning is done for future then the object is to forecast, almost foresee, the future and coordinate accordingly whereas when planning is for coordination we coordinate as events unfold while work-

ing in the general direction of the overall plan/objective. Thus, 'planning for coordination' primarily focus on the cross-functional perspective within the project – to create local order in a fundamentally disorderly situation, i.e. project work – whereas in 'planning the future' it is the time perspective, i.e. the future, that is the focus assuming that when the future is known order will emerge through alignment. A critical element in 'planning for coordination' therefore becomes communication and the elicitation of tacit knowledge. In 'planning for coordination' it is therefore the planning process that counts whereas in 'planning the future' it is more the plan that counts.

Since communication is a critical concept in 'planning for coordination', we must define it. Communicate is derived from the Latin word commun and a suffix 'ie', derived from 'fie', which means 'to make' or 'to do'. Thus, to communicate is 'to make something common' (Bohm 2004), and the purpose is to coordinate actions by the means of reaching an agreement communicatively, without reservation (Habermas 2003). Habermas (2003) uses the theory of speech acts developed by (Austin 1975) as his point of departure to develop his theory of communication. Speech acts are actions involving speaking, and we understand a speech act when we know what makes it acceptable. Of course, this is a matter of objective conditions of validity that the hearer cannot infer directly but only indirectly through the acceptability of four validity claims. Whereas a grammatical sentence must fulfill only the claim of comprehensibility, a successful speech act (a communicative action) must satisfy three additional validity claims (four in total);

1. It must count as true for the participants insofar as it represents something in the world.
2. It must count as truthful insofar as it expresses something intended by the speaker.
3. It must count as right insofar as it conforms to socially recognized expectations.

Already here we understand why a plan is less useful than planning – a plan only has to be comprehensible whereas planning as a communicative process must also be true, truthful and right to gain acceptance and hence commitment. Indeed, once people commit to what they think is right, orally or in writing, they are more likely to honor that commitment, even if the original incentive or motivation is subsequently removed (Cialdini 2001).

To develop the notion of planning as communication further, we must – as (Habermas 2003) does – theory make a clear distinction between sensory experience or observation and communicative experience or understanding. Observation is directed at perceptible things and events (or states); understanding is directed toward the meaning of speech acts, see **Figure 4**, so we are talking about either direct access through observation of reality or communicatively mediated access through understanding a speech act concerning reality. This will inevitably induce distortion and hence make direct observation a preferable approach in communicatively mediated access – a finding highlighted in lean manufacturing environments as well, see for example (Jackson 2006). With the finding from other research that about 85% of leaders and managers can be called relatively closed-minded, see (Nutt 1998), we understand that separating the planners and the doers as in traditional planning environments is potentially disastrous, as (Sussland 2002) also points out.

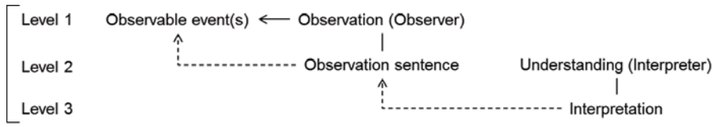

FIGURE 04. *From Observation to Interpretation via Communication (Habermas 2003).*

Furthermore, without good relations, communication will fail because communicative actions may fall prey to so called strategic actions, or communication primarily aimed at furthering self-interest by means of influence at the expense of reaching an understanding (Habermas 2003). Hence, plans by themselves are almost without value in this context.

Regardless of the efforts made at satisfying these validity claims, there will inevitably be miscommunication. According to (Baldoni 2004), there are two kinds of miscommunication; inadvertent and purposeful. Luckily, there are ways of dealing with purposeful miscommunication, such as (Grice 1991):

1. Exhibit good will – try to speak clearly and try to listen well.
2. Set clear objectives – people need to know what is expected to perform well and communicate clearly.
3. Ask for feedback – feedback provides an opportunity to correct the communication to reduce the gap between what we believe we communicate and what others perceive we communicate.

The purpose is to help the people in the planning process identify hidden assumptions and make them explicit so that they can engage in communicative action. The work of (Habermas 2003) and (Bohm 2004) is essential here and only dialogue constitutes communicative actions. With reference to **Figure 5**, persuasion and discussion are strategic usage of language whereas dissemination is merely the spreading of information more according to the traditional transmission-oriented approach to communication and planning. While **Figure 5** is not an exhaustive overview, it includes some of the most important usages of language that are likely to take place in projects, which we can break further down as:

1. Ordering (special case of dissemination) – a person tells another what to do. This is the classic old-style of management, and it is quite common today as well on many shop-floors. This should really be the last resort of communication as it, for example, is ineffective for the overall system over time, not to mentions what happens if the personnel that provide the orders are missing.
2. Teaching/presenting (special case of dissemination or dialogue depending on the approach) – a person presents subject matters for an audience. This can vary from the almost classic one-way monologue to a highly interactive two-way dialogue. Teaching is nonetheless one of the least effective ways to communicate knowledge as John Holt points out, as quoted by (De Geus 1988). At best, 40% of what is taught is received, in most situations it only about 25%.
3. Persuasions and discussion (argumentation) – some persons try to convince others about their points of view. This is also known as rhetoric – the art of making speeches, which originated in ancient Greece. It was quintessential for anybody who wanted high office. However, rhetoric degraded, to the dismay of Plato, into concerning itself with the means of persuasion and not with the ends, see (Honderich 1995). Persuasion thus understood is mostly a one-way affair. Argumentation, however, is two-way. Both can be intensive and frequent, and both concern the same objective – influence and convince others. However, there is a major difference –discussions are more confrontational and therefore more susceptible to our defensive routines because assumptions are not in the open and up for discussion. In fact, (Bohm 1993) points out that its linguistic roots are 'percussion' and 'concussion' and that "Discussion really means to break things up. It emphasizes the idea of analysis, where there may be many points of view" (Bohm 1993).
4. Dialogues – persons engage in "... a stream of meaning flowing among us and through us and between us – a flow of meaning in the whole group, out of which will emerge some new understanding, something creative" (Bohm 1993). Dialogues therefore are multi-directional, synchronous and very intensive. Assumptions are fully exposed and shared. They may, however, stretch over years. It is important to note that what most people call dialogues are essentially conversations and not dialogues.

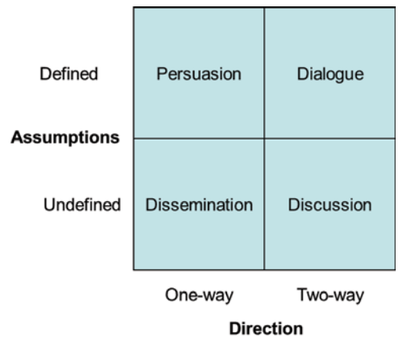

FIGURE 05. *Use of Language in Corporations.*

From this discussion we understand that planning must primarily be a dialogue and secondary a discussion when needed. Unfortunately, many approach planning more through dissemination and persuasion because the planners and those executing the work are separated not only in time and space but also in person and understanding.

There are also nonlinguistic means to improve communication and commitment through the process itself. The SECI process originated from the work of (Nonaka and Takeuchi 1995), see **Figure 6**, and it is very useful to help us understand this in greater detail.

First of all, the acronym SECI consists of the first letters of the four modes of knowledge conversion – Socialization, Externalization, Combination and Internalization. These four knowledge conversions consist of four possible configurations of tacit- versus explicit knowledge. These terms were first proposed by (Polanyi 1966). He actually proposed a dichotomy in three; 1) explicit knowledge, 2) implicit knowledge and 3) tacit knowledge. While most agree on the definitions on the explicit type of knowledge, the definitions of tacit knowledge vary – also because some view implicit knowledge as a type of tacit knowledge. Explicit knowledge can be defined as 'knowledge that can be fully expressed and communicated clearly', which includes all codified knowledge, rules, procedures, methods and so on. Implicit knowledge is according to (Polanyi 1966) another form of expressive knowledge, but it is not expressed due to various settings such as cultural customs, organizational styles and so on. Tacit knowledge, on the other hand, is a type of elusive and illusive 'awareness' of individual that cannot be expressed in words – a part of this type of knowledge is what (Johnson-Laird 1983) refers to as mental models which includes schemata, paradigms, perspectives, beliefs and viewpoints. From this (Polanyi 1966) has been credited with two much quoted sentences – "we can know more than we can tell" and "we know more than we realize".

While explicit, and to some extent the implicit, knowledge is quite straightforward to manage and corporations have according to (Sveiby 1997) "...sunk billions of dollars..." in Knowledge Management (KM) solutions to capture knowledge without much results. However, the great irony is that tacit knowledge embodies the true competitive advantage for companies (Cavusgil, Calantone et al. 2003) because it is not easily transferable or decipherable for other corporations than where it was initially conceived. In the context of planning, this is of utmost importance – it means that a planning system must draw insight even from tacit knowledge of the project team to be truly effective, which is exactly why the SECI process is highly relevant here.

The SECI process starts with the Socialization mode, first. This is because knowledge resides in people – and only in people from an organizationally point of view. This means that the project planning meeting is not just a necessary evil to coordinate, but they are absolutely crucial for learning. In fact, some of the most successful companies (Nonaka and Takeuchi 1995) discuss, applies brainstorming camps and parties to help this mode of knowledge conversion work effectively. This is how they build field where people can share mental models and experiences.

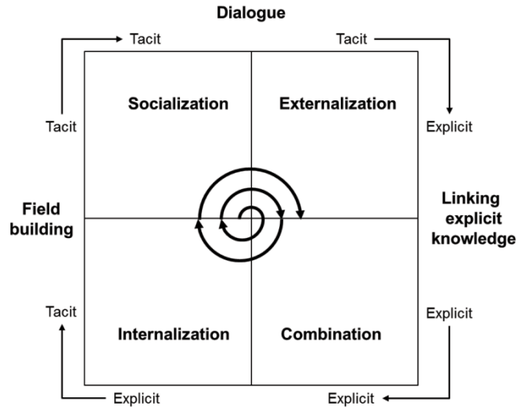

FIGURE 06. *The SECI Process. Derived from (Nonaka and Takeuchi 1995).*

The knowledge spiral leads us from the socialization mode to the externalization mode where the tacit knowledge is converted from tacit knowledge to explicit knowledge and hence made available for the rest of the organization. The main vehicle for this is dialogues. Here, we can also find storytelling, models, metaphors, hypotheses, concepts and analogues useful. Due to the relative inaccessible nature of tacit knowledge, metaphors and analogues are the most common approaches.

Once the knowledge is made explicit, it can be linked with other explicit knowledge and yield new insights. This takes place in the combination mode. This is the typical focus for many in knowledge work, but we are only half-way. In terms of the project planning meeting, this is important to focus on what was planned, handle deviations and what must be executed forward – explicit knowledge.

In the next step in the knowledge spiral we go to the final knowledge mode – internalization. This means to truly grasp the explicit knowledge and make it our own understanding and add to our current tacit knowledge. One of the most effective ways of doing for most people this is the learning by doing approach. This was an integral element of the extremely successful Training Within Industry (TWI) initiative in the US during World War II in which more than 1.75 million people were certified in more than 16,500 plants. In fact, according to (Dinero 2005), Toyota has more or less used the same system unchanged for more than 60 years with great results.

From this discussion, we understand that if we conceive of planning as an activity that is based on facts transmitted through utterances, then

it follows that communication must be one of the primary vehicles of planning. However, no one can genuinely think outside the box. Thus, we have not solved planning for surprises in a satisfying degree. For that to be achieved, we must take the step more fully and reject planning in the traditional sense and rather augment the project planning process by agility, which is done next.

4. Augmenting Planning by Agility - The Principles

Agility is adapted from the military domain. The work of John Boyd (1927 – 1997) is highly relevant in this respect, and he would have rather stated that maneuverability is obtained by getting on the inside of the enemy's decision process. This means that you know what the enemy will do before he does, but then you have already adapted and he is thrown off balance and in history panic has often been the result even in vast superior forces. Hannibal's defeat of the Romans in the battle of Cannae in 216 BC is perhaps the first documented example (Lind 1985). It was, however, Blitzkrieg that made it famous and an established doctrine now used by leading armies worldwide.

Boyd discovered first hand that contrary to common belief, there were times when the less maneuverable of two, roughly comparable competing jetfighters won an air combat. Boyd explained this fact by an ability of the less maneuverable, but more agile, jetfighter to more rapidly change. For example, the more maneuverable jetfighter is capable of taking a tighter turn, but the more agile jetfighter can more rapidly change from one turn to another – although the turn is not as tight as the turn for the more maneuverable jetfighter. Boyd, then, concluded that "The ability to shift from one maneuver to another more rapidly than an adversary enables one to win in air-to-air combat"[1]. In fact, (Morris 1993) describes maneuver warfare as a method for seeking a decision in battle with the greatest economy of effort. The focus is on the enemy, not ground, and speed of action and reaction must be faster than that of the enemy.

Boyd formulated his insight in what became known as the OODA loop, see **Figure 7**. It starts by observing what the current situation is. Given these observations, the decision-maker(s) have to orient themselves by setting the observations in context, hold it up against abilities and experiences, taking into account problems at hand and analyze and synthesize the situation. After orienting themselves, the decision-maker(s) must decide what to do. The decision is implemented and leads to action. From these four steps there is continuous feedback to observations – thinking (orientation), decisions and actions impact observations or our belief of what we observe. Note that there are no explicit targets. There is only implicit guidance and control. This includes the intent (what is to be accomplished), rules of engagement (procedures), policies and the like. It also includes what not to do, which is typically more important to give clear messages about than what to do because the very essence of agility lies in local decision-making by those that face the situation on the ground. There are a number of important consequences of agility for planning:

1. Detailed plans made early are meaningless – circumstances change and render detailed planning obsolete unless it is almost real-time.
2. Planning must be conducted by those closest to the action which implies that central planning on a number of issues is not only impossible but also harmful – they lack the necessary insight to make good decisions.
3. Many important aspects of planning are impossible to succinctly put into plans which mean that planning is largely a communication process.
4. Risk and uncertainty on a short-term, operational level cannot be handled by advanced modeling because the richness of information makes it impossible on such short notice. Risk and uncertainty must be handled by completing the OODA loop quickly and thereby risk and uncertainty is handled in the short, operational term by agility.

In a project this means that the quicker the planning loop is performed, but not quicker than what can be realistically performed, the more successful will the project be in planning and execution. Although, technology can help – it can be a double-edged sword. In fact, John Boyd noted that "…complex hardware and systems tend to focus organizations inward, which can accelerate the trend towards confusion, disintegration, and collapse" (Richards 2003). It is the process of project planning that count – not the plan; and project planning is essentially a process of communication.

1. See his work 'Strategic Game of ? and ?'. Unfortunately, John Boyd never published his work officially.

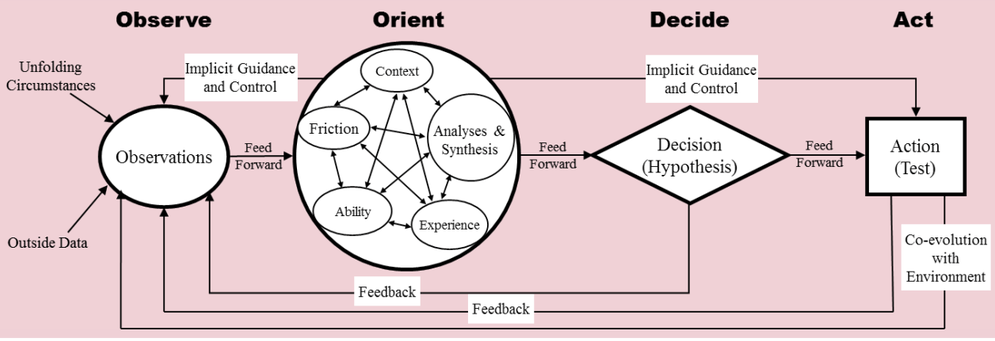

FIGURE 07. *The OODA Loop. Adapted from John Boyd in (Richards 2003).*

This discussion corresponds well with (Lissack and Roos 2001) who point out that decision making processes and models are often based on four false assumptions:

1. The world is stable enough that changes that may occur are foreseeable.
2. Prediction is possible.
3. Boundaries are clearly defined.
4. Outcomes are more important than processes.

As a consequence of the above assumptions, decision makers often fail to create, develop, or exploit opportunities. We act as though we are in control of events suffering from the Illusion of Control. Illusion of Control refers to situations where the decision-maker act as if they exert control over processes that are in fact determined by chance mechanisms. It was (Langer 1975) that introduced the concept, and she stated that the illusion is most likely to occur in situations where, although chance determined outcomes, cues are present that are more typically associated with outcomes determined by skill. These include factors such as competition, choice, familiarity, cognitive activity and involvement. Sequences of successes or failures will significantly impact this phenomenon. While research is not conclusive, a recent study suggests that experiencing an increasing rate of success can create the false impression of learning the correct strategy (Ejova, Navarro et al. 2013) increasing the Illusion of Control.

From this discussion, it follows that agility is probably the most reliable approach towards handling risk and uncertainties. Next, the implications of this on improving project planning is discussed.

5. Improving Project Planning

The Earned Value Management (EVM) method is the most recognized method to report status and to analyze project cost, schedule and performance (Sumara and Goodpasture 1997). It's attractiveness is related to some good performance metrics such as the Cost Performance Index (CPI) and that experience shows that after just 15% - 20% completion of the project, project management can predict both time and cost at completion fairly well – see (Fleming and Koppelman 2005) for an overview. Despite these advantages, which makes EVM a good point of departure for further development, (Yong-Woo and Ballard 2000) have shown that the approach suffers from the limiting assumption that activities and cost accounts are independent and by "making BCWP (earned-value) a priority in releasing assignments to the field which prevents quality assignments, which in turn results in unreliability of work flow". It is also recognized that EVM can be too complicated for many to master, see (Fleming and Koppelman 2005).

The Last Planner System (LPS) is another leading project planning approach. It was developed by H. Glenn Ballard and Gregory A. Howell – the motivation for developing this approach was a key finding from (Ballard and Howell 1998) that only about half of the assignments made to construction crews at the beginning of a week were completed when planned. To improve this, they developed the LPS. A very good overview of LPS is provided by (Ballard 2000) in his PhD dissertation. There, he recognizes (Koskela 1992) as the foremost production theorist in construction and he obtains several important notions:

1. The definition of "project" provided by (PMI 2008) is misleading because it focuses only on outputs and on an untested assumption of uniqueness that has discouraged learning from other industries. This in turn, has given focus on conversion activities while ignoring the importance of flow- and value activities. The problem with this is that it leads to a contracting mentality, which facilitates the management of contracts rather than the management of production or flow. Productivity improvement is therefore rare.
2. There are also consequences for how projects are controlled (Koskela and Huovila 1997). Traditionally, the objective is to detect negative variances from target and then deploy corrective actions, which is quite different from being proactive and avoid variances.
3. The five design criteria from (Koskela 1999) are also true for LPS:
   a) The assignment shall not start until all the items required for completion of a job are available (a sound job). The person or group that produces such assignments is called the "Last Planner" (Ballard and Howell 1994).
   b) The realization of assignments is measured and monitored using Percent Planned Complete (PPC), which is the ratio (in percentage) between the number of planned activities completed divided by the total number of activities committed/promised.
   c) Causes for non-realization are investigated and countermeasures deployed. This represents continuous improvement.
   d) Maintain a buffer of executable assignments.
   e) Prerequisites for upcoming assignments must be made ready actively. This is essentially a pull mechanism.

Conceptually, LPS has three hierarchical levels (Ballard and Howell 1998):

1. From the initial planning we get the project budget and schedule, and it pushes completions and deliveries onto the project.
2. The look-ahead planning is pulling resources into play and in so doing further adjusts and details budget and schedules. Important to this planning is the detection of unresolved issues ahead of execution. By solving these issues the project execution can continue uninterrupted.
3. Commitment planning is based on an evaluation of what can be done, taking the actual situation into account, compared what should be done (as outlines in the higher planning levels). Based on this evaluation people commit themselves to the plan. This is the starting point for production control. The actual commitment planning takes place in a regular – for example, weekly – meeting where all major stakeholders presents their week plan, coordinates it with the other stakeholders and commit themselves to what to do in the coming week.

Finally, we should notice that the PPC on non-lean processes are typically in the 35% - 65% range, whereas after LPS is implemented performance typically rise to 75% - above 90%, see (Ballard 2000). In fact, better than 70% was very rare prior to LPS (Ballard and Howell 1998). With this in mind, we can investigate some crucial differences between EVM and LPS:

1. In LPS pull techniques are used to govern the flow of materials and information through networks of cooperating specialists (Ballard 2000); in contrast, EVM is push-oriented for releasing the information and materials.
2. In LPS project control is obtained via proactive problem solving and execution (Ballard 2000); whereas, control in EVM relies on eliminating/reducing detected variances after-the-fact.
3. Feedback loops are included at every level and dimension (cost, quality and time) in LPS to make rapid system adjustments eliminating waste, (Ballard 2000); whereas in EVM such adjustments are not included un less it has taken place (after the fact).

4. In LPS, decision making is distributed in design production control systems (Ballard 2000); by comparison, in EVM decision making is more centralized.
5. In LPS a buffer of sound assignments is maintained for each crew or production unit (Ballard 2000); in contrast, the EVM method has no system for such buffering.
6. EVM only considers managing a project at the macro-level. This is necessary but insufficient for the success of projects. LPS encompasses project- and production management, and formally recognizes that any successful project undertaking will inevitably involve the interaction between project- and production management (Abdelhamid, El-Gafy et al. 2008).

Thus, there are a number of important differences between the EVM and LPS frameworks. However, what the true difference between these two schemes in terms of production planning and –control has been somewhat unclear.

The notion in much of the literature, and particularly among practitioners, has been that pull is kanban or Make To Order (MTO) meaning that a product is only made when the customer has requested that specific product (Hopp and Spearman 2004). While this is true on the business level, it is incorrect on a tactical level. Thus, (Hopp and Spearman 2004) try to sort this out by distinguishing between strategic pull and tactical pull.

Strategic pull means that products are made according to demand and not according to forecasts and the like, which is push, whereas tactical pull is a system that places explicit limits on Work In Progress (WIP). It has nothing to do with eliminating waste – it is therefore not strange that Shingo once said that "'Eliminating waste' is a nonsensical slogan" (Hopp and Spearman 2004). The mistake often done is mixing the tactics of implementing lean (tactical pull) with strategic pull so that that lean and pull became synonymous irrespective of whether we talk about strategic level or tactical level.

Figure 5 presents a common CONWIP system. Here, a global pull is sent to activity Ai which triggers a push of work through the subsequent activities. Unlike, in a kanban system, the resting states of the buffers is empty except at the start and finish of the cycle, see (Bonvik and Gershwin 1996), leading to reduced inventory. But there are disadvantages; due to lack of local feedback in CONWIP systems, a failure of a machine will lead to downstream starvation and upstream congestion. In kanban these problems will not occur. Yet, overall, (Bonvik and Gershwin 1996) concludes that CONWIP is a better approach than pure kanban. There are also studies indicating the CONWIP systems (either ordinary or Hybrid) can be applied in high-variety/low-volume environments with success, see for example (Slomp, Bokhorst et al. 2009). The level of WIP is not directly relevant in projects because many components are one off. Therefore, in projects CONWIP is under all circumstances better than kanban.

With this in mind, it seems that combining LPS and EVM is the best approach. This was done some years ago (Emblemsvåg 2014a, b). The marriage between EVM and LPS takes place at the period plan level where the 5-8 week (a given period) look-ahead planning takes place. The introduction of period plans embeds the look-ahead functionality of LPS and greatly improves the EVM reliability as well. The fact that these plans focus only a given period ahead is just as important as the fact that they look ahead. By start following up closely a certain period ahead, the project team can maneuver out of problems that may arise. Long leading time items are, of course, followed up explicitly and differently since they often have a longer lead time than 5-8 weeks.

This maneuverability is achieved by looking ahead at a set of predefined and standardized conditions for execution for each line in the plan (often called assignments, tasks or activities or similar) as prescribed by LPS. These conditions for execution serves as an explicit limitation of WIP, and we have essentially a local CONWIP system. Furthermore, only assignments in the plan that are executable are to be started. This is essentially a blocking device that will lead to upstream congestion and downstream starvation if no countermeasures are swiftly in place. Therefore, by maintaining a buffer of executable assignments is crucial for avoiding this problem as LPS highlights. Essentially, this is a pull system. LPS has a clear pull element and some push, but the push concerns making assignments executional and not to the overall project plan for the project.

What is missing in LPS is a stronger push part related to the overall project plan. In LPP, the EVM secures a push, but due to the LPS system on the tactical level we avoid the dysfunctional aspects of EVM. The marriage of EVM and LPS is achieved operationally by defining work packages so that we get a 1:1 relation (in most cases) between assignments in the period plan and these work packages. This gives a very good way of tracking physical progress, the CPIs gives physical meaning to the supervisors and the EVM becomes difficult to manipulate, which is one of the worries voiced by (Kim and Ballard 2000). LPS also gains by being linked into the EVM strengths. In a sense, LPS makes EVM work as originally intended, and we get a strong CONWIP system.

With respect to the topic of this paper – how agility is a better approach for dealing with uncertainty and risk than trying to forecast everything – we see some obvious links from the discussion above:

1. EVM provides an overall project plan of some detail defining the intent of the project and also providing implicit guidance and control, see **Figure 7**. It is crucial that this plan does not become too constricting as that will cripple maneuverability. Such constrictions arise from too narrowly defined activities. Focus the efforts on the activities that require coordination and let the rest have great freedom to severe as buffers for effective usage of manning. From this, it also follows that a multi-skilled workforce is highly valuable another feature found in lean manufacturing.
2. The Observe and Orient in **Figure 7** is achieved with the LPS system and its look-ahead planning where a focus on the conditions for execution will reveal any problems to maneuver around and in the regular planning- and coordination meeting the project team will decide how to deal with any issues.
3. The regular meetings where the project is operationally coordinated is where people communicates their preliminary plans. This is a meeting where tacit knowledge and experience can be brought to bear on issues at hand so that the team commit themselves to the best possible course going forward at any given time. Their individual plans are therefore adjusted to the overall best for the project but not by decree but by an understanding achieved through dialogue.

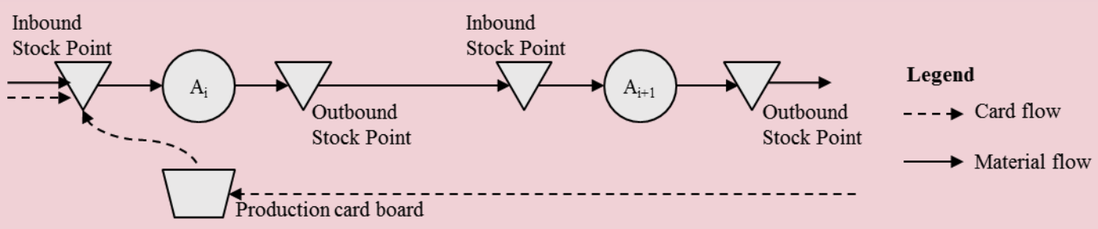

FIGURE 08. *Common CONWIP.*

In (Emblemsvåg 2014a) a LPP case is presented discussing the approach in more detail to which the interested reader is referred. LPP works as several cases confirm and the utility of LPS is documented on an even greater scale, and it shows that 'planning for coordination' to secure agility and hence achieve maneuverability is a better approach than trying to forecast the future. This does not mean, of course, that the LPP and LPS approaches are perfect. They are applicable for project related work and due to the nature of project related work personal skills for the project management team is still of great importance. However, the better the tools are the more likely it is that great people will do an even greater job.

In short; EVM tells you what you should do whereas LPS tells you what you could do, and agility is secured by rich dialogues on a regular basis fostering both effective feedback (pull) and feed forward (push) trying to close the gap between the should and the could. The quicker this loop goes – weekly or even daily – the more agile the project execution becomes, and the better the project management team is equipped to handle both risk and uncertainty.

Before closing this paper off, some of you might wonder how this differs from Scrum, Extreme Programming, Lean Software and Crystal and other so called agile methods. This is briefly discussed next.

6. Agile

First of all, agile methods are associated with software engineering (Meyer 2014), although they are expanding to other industries (Sutherland 2014). Agile ideas date back to the development of Extreme Programming in the 1990s, but reached fame with the appearance in 2001 of the "Agile Manifesto", The manifesto is then broken down into twelve principles, and they are:

1. Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.
2. Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.
3. Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
4. Business people and developers must work together daily throughout the project.
5. Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.
6. The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.
7. Working software is the primary measure of progress.
8. Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
9. Continuous attention to technical excellence and good design enhances agility.
10. Simplicity – the art of maximizing the amount of work not done--is essential.
11. The best architectures, requirements, and designs emerge from self-organizing teams.
12. At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

These principles rests upon five general tenets or assumptions, or 'values' as the agile proponents like to call them (Meyer 2014);

1. Redefined roles for developers, managers and customers.
2. No "Big Upfront" steps.
3. Iterative development.
4. Limited, negotiated functionality.
5. Focus on quality, understood as achieved through testing.

It is important to remember that agile methods are a set of approaches that share many commonalities but also some peculiarities. Each approach has their strength and weaknesses as documented by (Meyer 2014) – there is much hype, some brilliant ideas and some outright poor ideas. Some of their weaknesses are so fundamental that it is unlikely that the approaches can be deployed effectively in large projects involving more than information work such as software development. For example, no upfront steps would seem to be disastrous in many large projects.

Due to space restriction, the discussion on agile methods is stopped here simply due to their limited applicability. This said, it is clear they offer some interesting ideas that will be explored in the future. For example, the rule that functionality cannot be continuously added but must be added at rather defined moments, are very useful for managing scope creep in projects. In software development, scope creep is endemic, but it is also common in other project-based industries such as shipbuilding and construction.

7. Closure

Forecasting is like predictions; difficult. Indeed, as Niels Bohr said; "Prediction is very difficult, especially about the future" (Ellis 2010). Yet, this is how planning has been conceived by many – an attempt to foretell the future. Handling risk and uncertainty have therefore been mathematical exercises. A far better approach is to conceive of planning primarily as a coordination- and delegation tool to enables high degree of agility. This improved agility is the principle approach towards handling risk and uncertainty. Thus, instead of trying to foretell the future; shape it broadly and maneuver around obstacles of risk and uncertainty in an agile approach as it were.

author

Dr. Jan Emblemsvåg is the former SVP of Ship Design and Systems in Rolls-Royce Marine with full profit and loss responsibility for that unit. His background includes a mix of management consulting, project management, risk management, production management and senior management positions in various industries, including telecommunications, automotive, furniture manufacturing and ship building / design. He is a doctorate of Georgia Institute of Technology, Atlanta, USA, and before that Norwegian University of Science and Technology, Trondheim, Norway. His latest book is "Reengineering Capitalism: From Industrial Revolution towards Sustainable Development". Springer. London. p. 332. ISBN 978-3-319-19689-3. Today he works as an independent consultant, Prof II at NTNU, hold talks and some board positions.

Abdelhamid, T. S., M. A. El-Gafy and O. Salem (2008). "Lean construction: Fundamentals and principles." The American Professional Constructor Journal 32(2):pp. 8-19.

Allvine, F. (1996). Marketing: Principles and Practices. Boston, MA, Irwin/McGraw-Hill.p.

Arrow, K. J. (1992). I Know a Hawk from a Handsaw. Eminent Economists: Their Life and Philosophies. M. Szenberg. Cambridge, Cambridge University Press:pp. 42-50.

Austin, J. L. (1975). How to Do Things With Words. Cambridge, MA, Harvard University Press.p. 169.

Baldoni, J. (2004). Avoiding Miscommunications. Darwin Magazine:pp. www.darwinmag.com.

Ballard, H. G. (2000). The Last Planner System of Production Control. Faculty of Engineering. Birminghan, The University of Birmingham. PhD Dissertation:pp. 191.

Ballard, H. G. and G. A. Howell (1994). Stabilizing Work Flow. Proceedings of the 2nd Annual Conference of the International Group for Lean Construction. Santiago, Chile:pp. 101-110.

Ballard, H. G. and G. A. Howell (1998). "Shielding Production: Essential Step in Production Control." Journal of Construction Engineering and Project Management 124(1):pp. 11-17.

Bernstein, P. L. (1996). Against the Gods: the Remarkable Story of Risk. New York, John Wiley & Sons.p. 383.

Bohm, D. J. (1993). "For Truth Try Dialogue." Resurgence 13(No. 156, January/February):pp. 10-13.

Bohm, D. J. (2004). On Dialogue. London, Routledge.p. 101.

Bonvik, A. M. and S. B. Gershwin (1996). Beyond kanban: creating and analyzing lean shop-floor control policies. Manufacturing and Service Management Conference Proceedings, Hannover, NH.

Cavusgil, S. T., R. J. Calantone and Y. Zhao (2003). "Tacit knowledge transfer and firm innovation capability." Journal of Business & Industrial Marketing 18(1):pp. 6-21.

Cialdini, R. B. (2001). Influence: Science and practice. Upper Saddle River, NJ, Pearson.p. 262.

De Geus, A. P. (1988). "Planning as Learning." Harvard Business Review 66(March-April):pp. 70-74.

Dinero, D. A. (2005). Training Within Industry: The Foundation of Lean. New York, CRC Press.p. 329.

Ejova, A., D. J. Navarro and P. H. Delfabbro (2013). "Success-slop effects on the illusion of control and remembered success-frequency." Judgment and Decision Making 8(4):pp. 498-511.

Ellis, A. K. (2010). Teaching and Learning Elementary Social Studies (9th Edition). London, Pearson.p. 432.

Emblemsvåg, J. (2003). Life-Cycle Costing: Using Activity-Based Costing and Monte Carlo Methods to Manage Future Costs and Risks. Hoboken, NJ, John Wiley & Sons.p. 320.

Emblemsvåg, J. (2010). "The augmented subjective risk management process." Management Decision 48(2):pp. 248-259.

Emblemsvåg, J. (2014a). "Lean project planning in Shipbuilding." Journal of Ship Production and Design 30(2):pp. 79-88.

Emblemsvåg, J. (2014b). "Lean project planning: Using lean principles in project planning." International Journal of Construction Project Management(Accepted for publication).

Emblemsvåg, J. (2015). Reengineering Capitalism 2016 : From Industrial Revolution Towards Sustainable Development. London, Springer.p. 332.

Fleming, Q. W. and J. M. Koppelman (2005). Earned Value Project Management. Newtown Square, PA, Project Management Institute.p. 232.

Gilford, W. E., H. R. Bobbitt and J. W. Slocum jr. (1979). "Message Characteristics and Perceptions of Uncertainty by Organizational Decision Makers." Academy of Management Journal 22(3):pp. 458-481.

Grice, H. P. (1991). Studies in the Way of Words. Cambridge, MA, Harvard University Press.p. 394.

Habermas, J. (2003). On the Pragmatics of Communication. Cambridge, Polity Press.p. 454.

Hines, W. W. and D. C. Montgomery (1990). Probability and Statistics in Engineering and Management Science. New York, John Wiley & Sons, Inc.p. 732.

Honderich, T., Ed. (1995). The Oxford Companion to Philosophy. New York, Oxford University Press.p. 1009.

Hopp, W. J. and M. L. Spearman (2004). "To Pull or Not to Pull: What Is the Question?" Manufacturing & Service Operations Management 6(2 Spring):pp. 133-148.

Hubbard, D. W. (2009). The Failure of Risk Management: Why It's Broken and How to Fix It. Hoboken, NJ, John Wiley & Sons, Inc.p. 281.

Jackson, T. L. (2006). Hoshin Kanri for the Lean Enterprise: Developing Competitive Capabilities and Managing Profit. New York, Productivity Press.p. 206.

Johnson-Laird, P. N. (1983). Mental Models. Cambridge, Cambridge University Press.p. 528.

Jones, M. E. and G. Sutherland (1999). Implementing Turnbull: A Boardroom Briefing. City of London, The Center for Business Performance, The Institute of Chartered Accountants in England and Wales (ICAEW).p. 34.

Kangari, R. and L. S. Riggs (1989). "Construction risk assessment by linguistics." IEEE Transactions on Engineering Management 36(2):pp. 126 - 131.

Kerzner, H. (2013). Project Management: A Systems Approach to Planning, Scheduling, and Controlling. Hoboken, NJ, John Wiley & Sons.p. 1296.

Kim, Y.-W. and H. G. Ballard (2000). Is the Earned Value Method and Enemy of Work Flow? Proceedings of the 8th International Group for Lean Construction Conference, Brighton, UK, International Group for Lean Construction.

Klir, G. J. (1991). "A principal of uncertainty and information invariance." International Journal of General Systems 17:pp. 258.

Klir, G. J. and B. Yuan (1995). Fuzzy Sets and Fuzzy Logic: Theory and Applications. New York, Prentice-Hall.p. 268.

Koskela, L. (1992). Application of the New Production Philosophy to Construction. Standford, CA, Stanford University, Center for Integrated Facility Engineering.p. 75.

Koskela, L. (1999). Management of Production in Construction: A Theoretical View. Proceedings of the 7th Annual Conference of the International Group for Lean Construction. I. D. Tommelein. University of California, Berkeley, CA:pp. 241-252.

Koskela, L. and P. Huovila (1997). On Foundations of Concurrent Engineering. Concurrent Engineering in Construction CEC97. C. Anumba. London, The Institution of Structural Engineers:pp. 22-32.

Langer, E. J. (1975). "The Illusion of Control." Journal of Personality and Social Psychology 32(2):pp. 311-328.

Laufer, A. and R. L. Tucker (1987). "Is construction project planning really doing its job? A critical examination of focus, role and processes." Construction Management and Economics 5(3):pp. 243-266.

Laufer, A. and R. L. Tucker (1988). "Competence and timing dilemma in construction planning." Construction Management and Economics 6(4):pp. 339-355.

Lind, W. S. (1985). Manoeuvre Warfare Handbook. Boulder, CO, Westview Press.p. 152.

Lissack, M. R. and J. Roos (2001). "Be coherent, not visionary." Long Range Plannig 34(1):pp. 53-70.

Marton, F. (1981). "Phenomenography - Describing conceptions of the world around us." Instructional Science 10(2):pp. 177-200.

McNeill, D. and P. Freiberger (1993). Fuzzy Logic. New York, Simon & Schuster.p. 320.

Meyer, B. (2014). Agile! The Good, the Hype and the Ugly. Zurich, Springer International Publishing Switzerland.p. 170.

Morris, A. R. (1993). "Manoeuvre warfare - can the British Army cope?" British Army Review 105(December):pp. 7-15.

Nonaka, I. and H. Takeuchi (1995). The Knowledge-Creating Company: How Japanese Companies Creat the Dynamics of Innovation. New York, Oxford University Press.p. 298.

Nutt, P. (1998). "Leverage, Resistance and the Success of Implementation Approaches." Journal of Management Studies 35(2):pp. 213-240.

Oehmen, J., Ed. (2012). The Guide to Lean Enablers for Managing Engineering Programs, Version 1.0. Cambridge, MA, Joint MIT-PMI-INCOSE Community of Practice on Lean in Program management.p. 202.

Peters, E. E. (1999). Complexity, Risk and Financial Markets. New York, John Wiley & Sons.p. 222.

PMI (2008). A Guide to the Project Management Body Of Knowledge (PMBOK Guide). Newtown Square, PA, Project Management Institute.p. 467.

Polanyi, M. (1966). The Tacit Dimension. New York, Anchor Day Books.p. 108.

Powner, D. A. (2008). OMB And Agencies Need to Improve Planning, Management, and Oversight of Projects Totaling Billions of Dollars. Washington DC, United States Government Accountability Office (GAO).p. 50.

Richards, C. W. (2003). A Swift, Elusive Sword: What If Sun Tzu and John Boyd Did a National Defense Review. Washington DC, Center for Defense Information.p. 88.

Savage, L. J. (2003). The Foundations of Statistics. New York, Dover Publications Inc.p. 310.

Slomp, J., J. A. C. Bokhorst and R. Germs (2009). "A lean production control system for high-variet/low-volume environments: a case study implementation." Production Planning & Control 20(7):pp. 586-595.

Sumara, J. and J. Goodpasture (1997). Earned Value - The Next Generation - A Practical Application for Commercial Projects. Project Management Institute 28th Annual Seminars & Symposium. Chicago, IL, Project Management Institute:pp. 13-17.

Sussland, W. A. (2002). "Connecting the Planners and Doers." Quality Progress(June):pp. 55-61.

Sutherland, J. (2014). The Scrum Handbook. Cambridge, MA, Scrum Inc.p. 86.

Sveiby, K. E. (1997). The New Organizational Wealth - Managing & Measuring Knowledge-Based Assets. Brisbane, Berret-Koehler Publishers, Inc.p. 275.

Taguchi, G., S. Chowdhury and Y. Wu (2005). Taguchi's Quality Engineering Handbook. Hoboken, NJ, John Wiley & Sons.p. 1662.

Tversky, A. and D. Kahneman (1974). "Judgment under Uncertainty: Heuristics and Biases." Science 185(4157):pp. 1124-1131.

Vygotsky, L. S. (1988). Thought and Language. Cambridge MA, The MIT Press.p. 285.

Webster (1989). Webster's Encyclopedic Unabridged Dictionary of the English Language. New York, Gramercy Books.p. 1854.

Yong-Woo, K. and H. G. Ballard (2000). Is the Earned Value Method and Enemy of Work Flow? Proceedings of the 8th annual conference of the International Group for Lean Construction. Brighton:pp. 10.

references