Toward a Conceptual Framework of Agile Methods: A Study of Agility in Different Disciplines

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ABSTRACT
Since the software crisis of the 1960's, numerous methodologies have been developed to impose a disciplined process upon software development. It is now widely accepted that these methodologies are unsuccessful and unpopular due to their increasingly bureaucratic nature. Many researchers and practitioners are calling for these heavyweight methodologies to be replaced by agile methods. The Agile Manifesto was put forward in 2001, and several method instantiations, such as XP, SCRUM and Crystal exist. Each adheres to some principles of the Agile Manifesto and disregards others. This paper proposes that these Agile Manifesto principles are insufficiently grounded in theory, and are largely naïve to the concept of agility outside the field of software development. This paper aims to develop a comprehensive framework of software development agility, through a thorough review of agility across many disciplines. We then elaborate and evaluate the framework in a software development context, through a review of software related research over the last 30 years.

Categories and Subject Descriptors
D.2.0 [**Software Engineering**]: Management – *life cycle, cost estimation, time estimation*

General Terms
Management, Measurement, Theory.

Keywords
Agile methods, manufacturing agility, conceptual framework.

1. INTRODUCTION
The formation of the Agile Alliance in 2001 and the publication of the Agile Manifesto [15] formally introduced agility to the field of software development (SD). Those involved sought to "restore credibility to the word *method*" [15]. The Agile Manifesto conveyed an industry-led vision for a profound shift in the SD paradigm, through 12 principles:

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- Satisfy the customer through early and continuous delivery of valuable software
- Sustainable development is promoted, facilitating indefinite development
- Simplicity is essential
- Welcome changing requirements, even late in development
- Deliver working software frequently
- Working software is the primary measure of progress
- Continuous attention to technical excellence
- Business people and developers must work together daily
- Face-to-face communication is the best method of conveying information
- The team regularly reflects on how to become more productive and efficient
- The best work emerges from self-organising teams
- Build projects around motivated individuals

The Agile Manifesto and its principles represent quite pioneering work in coalescing and extending the critique of formalised software methods over the past decade or so (e.g [1, 13, 14] and have been well received by practitioners and academics.

2. SHORTCOMINGS OF THE STUDY OF AGILITY IN SD
There is no universally accepted definition of an agile method in the field of Information Systems Development (SD). Cockburn [7] even dismisses the existence of an agile method altogether, claiming that it is something that developers can only aspire to, and only hindsight can determine whether an agile method was actually adhered to.

The reason for such a lack of consensus is that the principles of agility expressed in the Agile Manifesto [15] lack grounding in management theory and philosophy, and do not consider the evolution of the concept of agility in fields outside SD. As a result, there are many methods currently in use which are all categorised as agile by those that use these methods. Each of these focus heavily on some of the principles of the agile manifesto and ignore others completely, but yet are portrayed by

some, not only as an agile method, but as the best agile method. Given that such vague and diverse interpretations exist, it is impossible to reach any conclusions on agile methods and their use.

Agility is not a concept unique to software development. Indeed it first appeared in the mainstream business literature in 1991 , when a group of researchers at the Iacocca Institute in Lehigh University introduced the term "agile manufacturing" [28]. The industry-based report aimed to provide the USA with a weapon to regain its pre-eminence in manufacturing, and described the emerging agile principles being adopted by US, European and Japanese firms as being the way forward. Since then manufacturing companies across many industries have gained a competitive advantage from such an agile philosophy [3].

However, a review of the agile manufacturing literature indicates that even now, 12 years later, those who study agile manufacturing are having the same problems as those studying agile methods in SD. There are many diverse and often contradicting definitions of agile manufacturing, the concepts lack a theoretical grounding, and consideration is not given to the differences between industries and organisations [3].

Therefore, the search for a definitive, all-encompassing concept of agility is not to be found simply through an examination of agility in other fields. Rather it is to be found through an examination of the underlying concepts of agility, namely flexibility and leanness [37, 39] which have much older origins. For example, lean thinking can be traced back to the Toyota Production System in the 1950s with its focus on the reduction and elimination of waste [34], the production of the Spitfire airplane in World War 2 [4]and even as far back as the automotive industry in 1915 [11].

3. RESEARCH METHOD

The objective of this paper is to develop a comprehensive conceptual framework of SD agility that can be applied to any SD project, enabling the true level of its agility to be established. This objective is achieved through a four step research process:

- A literature review on the concepts of flexibility and leanness, and their relationship with agility, is carried out. This review includes research on agility across manufacturing, finance, management, labour and marketing among others, in order to appreciate the multi-disciplinary nature and evolution of these concepts.
- A clear definition of each term, based on the literature review, is proposed. Due to the broad nature of each of these terms, and to the diverse interpretations of these terms that exists, these definitions are constructed and adjusted in an incremental manner.
- The definitions of flexibility and leanness are then merged to form an initial working definition of agility. This initial definition is then subsequently refined in the light of further relevant research on the relationship between agility and the flexibility and leanness concepts. A conceptual framework of agility is then put forward, using this refined definition as a base. Given the diversity of the literature, the researchers sought to ensure that the framework represents agility in its most general sense.
- The final stage was to apply the framework to an SD context. This was done through a review of the 30 odd years of general SD literature, to extract any policies, actions or behaviours of SD teams which would be classified within this framework. The review had to be more inclusive than just agile methods *per se* as these did not appear until the late 1990s, although SD practitioners have been applying agile principles for much longer, even if they did not know it.

4. TOWARDS A FRAMEWORK OF AGILITY FOR SD

4.1 Flexibility

Flexibility is often interpreted as per its simple dictionary definition as simply:

"the ability to adapt to change".

However, the body of research on the definition of flexibility indicates such an interpretation is too simple.

Firstly, the word "embrace" is a better reflection of flexibility than "adapt to". Hashimoto et al [24, 25] refer to *robustness* or *resilience* as a component of flexibility. Robustness or resilience is the ability to *endure* all transitions caused by change, or the degree of change tolerated before deterioration in performance occurs *without* any corrective action ([24, 25]. This concept indicates that in order to be truly flexible, an entity must not only be able to adapt to change by taking steps, but must also be able to embrace change by taking none. Also, the literature makes a distinction between defensive and offensive strategies [17]. This raises the issue that, when change occurs, not only can an entity attempt to return to its original state, but it can take advantage of the change to place itself in a better position. The term "*adapt to"* implies that an entity is homeostatic, and that its only objective in the face of change will be to return to its original state. "*Embrace"* implies that the entity may not only try to return to its original state but may capitalise on the change and improve on its position. As well as using flexibility to anticipate uncertainty, it can also be used proactively to permit a company to positively impact its environment [16]. This concept argues that proactive steps may "not just anticipate change, but may create it" [35]. The words "adapt to" implies that change is the driving force and the entity's actions are as a result of that force. "Embrace" signifies a *two-way process* where the entity not only reacts to change but can also influence it.

There is a difference between *proactive* and *reactive* flexibility [17] also known as *initiative* versus *response* [19]. This concept recognises the fact that an entity is not helpless while waiting for change to occur and that steps can be taken *in advance of* change as well as in response to it. The simple example of periodic inspection and preventative maintenance of equipment is a proactive approach to combating machine failure, as opposed to repair and replacement of equipment after failure, which is a reactive one [16].

It is important to note that *an entity itself is not flexible.* Rather, an entity obtains this flexibility through the various sub-systems, resources, and activities that comprise that entity. For example Correa's [9] opinion is that "an organisation is only as flexible as its people".

The literature also highlights a distinction between internal and external flexibility. This dimension of flexibility is defined as "the area in which the flexibility is created" [17]. It reflects the fact

that an entity *may not be a closed system.* Rather it may interact with other systems in its environment and may be able to use these interactions to handle change. Goudswaard & de Nanteuil [21] illustrate this concept through labour flexibility referring to internal flexibility as the ability of an organisation to vary employee's duties, working hours or salaries, while external flexibility refers to the ability of an organisation to draw resources through subcontractors, short-term contracts or temp agencies.

Much of the literature indicates time as a primary measure of flexibility [12, 23, 40]. Golden & Powell [17] describe the temporal dimension of flexibility as the "length of time it takes for an organisation to respond to environmental change" or to "adapt within a given time frame". Furthermore, as change may arise due to environmental influences the temporal dimension must incorporate the length of time taken for an entity to recognise that change has occurred, to decide on what action to take, and to carry out that action. As time is such a central criterion to evaluating and measuring an entity's flexibility, it is imperative that it is referred to in the definition. However, careful wording is required, since speed alone should not be taken as a measure of success. Volberda [42] compares time taken to adapt to change against the variety of that change, acknowledging the fact that rapid response to familiar change is not necessarily better than a slow response to large, strategic change.

This research proposes the following refined definition of flexibility which reflects the robust, proactive, reactive and temporal dimensions of flexibility

> "the ability of an entity to proactively, reactively or inherently embrace change in a timely manner, through its internal components and its relationships with its environment."

4.2 Agility v. Flexibility

Lindbergh [31] and Sharafi & Zhang [37] indicate that agility is made up of two components. The first is flexibility, but it shares equal prominence with the second, which is *speed.* Essentially, an organisation must be able to "respond flexibly" and "respond speedily" [2]. Terms such as "speed" [38], "quick" ([10, 22, 30, 45], "rapid" [26] and "fast" [46] occur in most definitions of agility. This reference to speed was discussed within the context of flexibility. However, as research on the definition of agility has placed such emphasis on rapidity, it merits an adjustment to the definition before it can be applied to the term *agile*.

Another distinction between agility and flexibility is the assumption that change is *continuous* and embracing it is an ongoing activity. This assumption was laid down in the key contribution of Goldman, Nagel & Preiss [19], where they described agility in general terms as "a continual readiness to change". The flexibility literature, and therefore the definition as it stands, makes no reference to continual change as opposed to a once off change.

For some, agile means to apply the concepts of flexibility throughout different parts of the organisation, and not to a specific part such as manufacturing or production processes [29]. This has led to the coining of terms such as "agile supply chains" [6], "agile decision support systems" [27], and "agile workforce" [41]. However, some suggest that agility is flexibility with an "organisational orientation" [6], in that it is applied *collectively* throughout the enterprise [19, 36]. This notion would be in line with Golman & Nagel's [18] "agile enterprise", Nagel & Dove's [32] opinion that agility must be viewed in a "business-wide context", and that of Gunasekaran et al [22] which states that agility is "not a series of techniques but a fundamental management philosophy".

Our definition of flexibility can be amended to reflect these differences, and can therefore be said to subsume the flexible component of agility. The modified definition now reads as:

> "the continual readiness of an entity to rapidly or inherently, proactively or reactively, embrace change, through its collective components or its relationships with its environment".

4.3 Leanness

Unlike the concept of flexibility, the notion of leanness is relatively straight-forward. It is "the elimination of waste" [33, 34, 43] and "doing more with less" [39].

Different authors have conflicting opinions regarding the benefits and drawbacks of using a lean approach. However, there is a general consensus that such an approach broadly consists of the following principles [33, 34, 39, 43]

- Utilisation of all resources is maximised, and no unnecessary resources are maintained.
- Simplicity of tasks, information flow and information processes is maximised.
- A product or activity should pass through the necessary components of an entity and the components of its partners in a single flow.
- A high level of quality must be maintained through defect prevention not correction. A "root cause" approach is taken to problem solving to maximise added value.

The proposed definition of leanness is:

> "the maximisation of simplicity, quality and economy"

4.4 Agility v. Leanness

Some believe that although agility exhibits similar traits to *leanness* in terms of *simplicity* and *quality,* the literature has identified one major difference in terms of *economy* [44]. Ultimate leanness is to eliminate all waste. Agility requires waste to be eliminated, but *only to the extent where its ability to respond to change is not hindered*. As this does not remove the need to be economical, only lower its priority, it is important that the definition of agility is modified to incorporate all elements of leanness, which was defined above as "the maximisation of simplicity, quality and economy".

4.5 Proposed Definition of Agility

After consideration of the literature on flexibility and leanness and, after accounting for the differences between these concepts and the concepts of agility, the final definition of agility in this study is:

"the continual readiness of an entity to rapidly or inherently, proactively or reactively, embrace change, through high quality, simplistic, economical components and relationships with its environment".

5. Agility Assessment Framework

Figure 1 depicts an assessment framework of ISD agility, using the definition as a foundation.

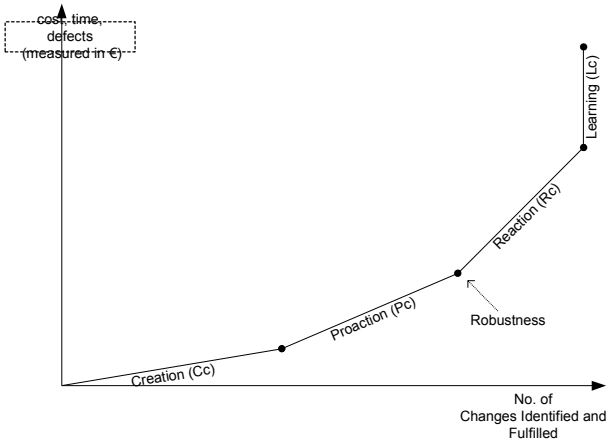

Figure 1: The Concept of Agility in IS Development

5.1 Explanation of the Framework

A brief explanation of agility as represented by Figure 1 is as follows:

- The over-arching objective of an agile method is to identify and handle change (represented by the x-axis).
- Identifying and handling change requires resources. The development team face the task of dealing with change while minimizing the cost, time and diminished quality required to do so. The fact that being agile is fuelled by resources is represented along the x-axis. The common denominator used to represent these three resources is €.
- The graph then depicts the four broad categories of activities an agile team can carry out in relation to change:
- Change Creation: This is where the ISD team are the primary instigators of change, as opposed to a team who are usually passive and only subjected to change that originates from the customer or from levels higher in the organization
- Proaction: This is where the ISD team takes actions to elicit changes before they actually occur. Prototyping is a prime example of this. The delaying of decisions and staging investment of resources are also examples of proaction.
- Reaction: These are actions taken by the ISD team in response to a change.
- Robustness: Robustness is often characterized as a component of agility. However, this framework recognizes that robustness is not an activity in itself but is a product of proaction. In other words, proactive activities, if done well, should reduce the need to react. The less reaction required, the higher the level of robustness.
- Learning: This is where the ISD team learns from the change process so as to be more creative, proactive and reactive during the next cycle.

The curve becomes gradually steeper to reflect the fact the well known fact that the later you detect the need to change, the more time, money and defects will be incurred [8].

5.2 Measuring Agile Activities Using the Assessment Framework

5.2.1 Measuring Creation, Proaction and Reaction

Measuring creative, proactive and reactive activities in terms of their level of agility is done by comparing the number of changes identified and fulfilled by an activity to the cost of carrying out that activity. The greater the number of changes per €, the more agile the activity.

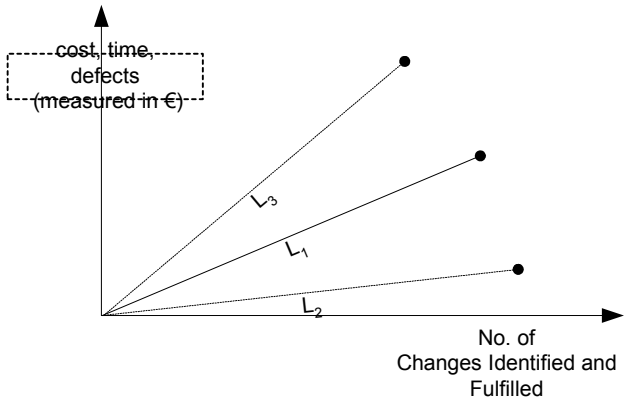

Figure 2: Measuring Creation, Proaction and Reaction

5.2.2 Measuring Robustness

Robustness, unlike the other aspects of agility is not a dynamic metric, and no activities can explicitly contribute to robustness. Recalling Hashimoto's [24] definition, robustness the ability to *endure* all transitions caused by change without having to take corrective action. In this framework, true robustness exists when the need to react is non-existent. Therefore, the less reactive activities in relation to a change, the more robust the process is.

5.2.3 Measuring Learning

The learning component of agility is not something that can be measured as easily as the other activities. The reason for this is that the inputs to this components, namely cost, time and defects can be measured, but the output cannot. This is because no changes are identified or fulfilled as a result of the learning process.

However, a measure of the effectiveness of learning can be drawn by extending Figure 1 to reflect the fact that change, and therefore the need to be agile, is a continuous process. This phenomenon is illustrated in Figure 3. So, if a team learn well from their first round of creative, proactive and reactive activities, the next round of activities should be performed even better. In graphical form,

this will mean that the next round of creative, proactive and reactive activities should exhibit a flatter curve.

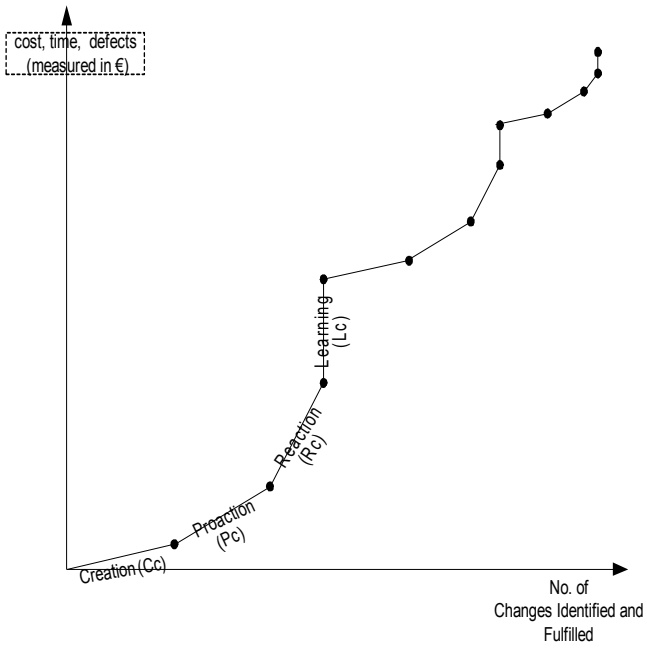

Figure 3: The Concept of Agility as a Continuous Process

6. Operationalising the Assessment Framework in ISD

Change and pressure drive entities of any discipline to be agile. However, it is impossible to derive a definitive list of drivers which are applicable to all disciplines. The conceptual framework in this chapter identifies potential drivers which are reasonably broad and are common to different disciplines such as manufacturing, finance and management.

- *Competition:* These changes include a rapidly changing market, increased cost pressures and competitors' responsiveness to market [5, 11].
- *Customers:* Demand for individualised products, sudden changes in order quantities and higher quality expectations [22, 29, 44].
- *Technology:* New methods of achieving objectives or technology to achieve those objectives become available [20, 37].
- *Social Factors:* Changing workforce expectations, new cultural, legal or political issues or environmental pressures are examples of social factors which drive the need to be agile [37].
- *Overhead:* Any team, or part of an organisation may be subjected to changes imposed from higher levels in the organisation [22, 29, 44].

6.1 Creation (of change)

The concept of change creation is very straight forward in ISD. In simple terms, any action or ability can be deemed to be change creating if it causes a change that would not have occurred had that action not been taken or that ability possessed. The most important thing to note is the wide-ranging meanings change can have in an ISD environment, discussed in the previous section. By referencing referring back to the five generic drivers of change once again, a number of change creation examples can be extrapolated. These examples are displayed in Table 1.

Source of Change	Type of Change	ISD Example
Customer	Changes in Demand	The ISD team may take action to encourage new requirements. For example, taking the time to select or develop a number of alternative IS solutions, apart from the single solution preferred by the client.
Competition	Increased Cost Pressures from Competitors	An ISD team may not just be part of a market experiencing cost pressures (competition), but may actually be the ones driving that change.
Technology	Change in technology or method used	A team may actively change hardware, software or methods to add more value for the client, instead of just being a passive victim of such change.
Social Factors	Changing workforce expectations	By empowering the workforce, and allowing them to shape and mould what the team does, their changing expectations may directly impact the project.
Overhead	Imposed changes	Instead of just adhering to changes that come down from above, a system should be in place where the ISD team can actually drive change back out through the whole enterprise.

Table 1: Examples of Change Creation in ISD

6.2 Proaction (in advance of change)

Proaction acknowledges that even if change can not be created, steps may be taken to predict change, minimise its negative impact, and maximise the potential to benefit from it. In the same vein as previous sections, Table 2 illustrates proaction in ISD using similar scenarios to before.

Source of Change	Type of Change	ISD Example
Customer	Changes in Demand	The ISD team may frequently interview clients and users, or may conduct prototyping sessions, to ensure that the inevitable requirement changes are elicited as soon as possible.
Competition	Increased Cost Pressures from Competitors	The ISD team may conduct market research on other projects, engagements and product offerings to ensure their projects are not conducting unnecessarily costly activities.
Technology	Change in technology or method used	An ISD team may spend extra time during design and development to ensure the IS can support multiple platforms and platform versions.
Social Factors	Changing workforce expectations	Regular feedback from the members of the team will help to catch any concerns, issues and expectations that emerge as the project progresses.
Overhead	Imposed changes	The ISD team may negotiate a lead time for the proposed change to be implemented, reducing the impact of the change as it can be phased in gradually.

Table 2: Examples of Proaction in ISD

6.3 Robustness (at the instant change occurs)

Robustness is a very simple concept in ISD, just as it is in any other discipline. Robustness is the inherent ability to absorb change. In ISD, a truly robust team should be able to absorb requirement changes, increased competition, new methods and technology, changing social conditions and imposed changes without any action necessary. However, in reality this is usually nothing more than a notional target. It is wrong to expect any team to absorb any change without having to take some minimal actions.

6.4 Reaction (in response to change)

In ISD, reaction refers to how quickly, cheaply and effectively the team can respond to change. Table 3 illustrates proaction in ISD using similar scenarios to before.

Source of Change	Type of Change	ISD Example
Customer	Changes in Demand	The ISD team may have access to the code libraries from other projects at their disposal, in order to have some of the work done should certain requirements come in.
Competition	Increased Cost Pressures from Competitors	The ISD team may have outsourcing options in place so as to be able to compete on price if necessary.
Technology	Change in technology or method used	The ISD team may ensure there are trainers on hand to skill-up the staff on any new technology that emerges.
Social Factors	Changing workforce expectations	The team structure can be left somewhat flexible so people can be assigned to new roles if problems arise.
Overhead	Imposed changes	The ISD team may bring in senior officials from head office to make the transition to new procedures quick and easy.

Table 3: Examples of Reaction in ISD

6.5 Learning (from change)

Learning in ISD refers to the ability of the team to reflect on how creative, proactive, robust and reactive they have been to change in the past, to enable them to be better at each in when future change arises (Table 4).

7. LIMITATIONS & FURTHER RESEARCH

The assessment framework outlined in this paper can help identify if activities contribute to agility or not. However, there are parts of an agile process which cannot be characterized as activities. For example, delaying a decision until the environment becomes clear is a major contributor to agility. However, the relative cost, time and quality factors of such a delay are difficult to quantify.

Another limitation is that current agile methods in ISD, such as XP are largely made of philosophies rather than activities. The cost, time and quality aspects of philosophies are also difficult to quantify. “Simplicity is essential” [15] is an example of this.

Future research should include an empirical application of this framework, to see if activities which are claimed to be agile actually do contribute to the identification and fulfillment of change, and also are economical in terms of the resources they consume. Also, it is important to test this framework to determine if ISD teams actually consider these metrics implicitly or explicitly when undertaking a project.

Source of Change	Type of Change	ISD Example
Customer	Changes in Demand	The ISD team could reflect on the changing requirements log to identify underlying trends which could be used to predict future changes i.e. every 6 months a requirement comes in to extend the server capacity.
Competition	Increased Cost Pressures from Competitors	The ISD team could do an analysis of how their processes and costs have changed in relation to those of competitors.
Technology	Change in technology or method used	The ISD team manager could learn from technology adoption problems in the past, and prepare for the same events in the future.
Social Factors	Changing workforce expectations	The ISD team manger could look at reasons why past team members have left, in order to anticipate changing expectations of new staff in the future.
Overhead	Imposed changes	The ISD team manager could look at how he/she could have got involved in the decisions over the imposed changes and the input he/she could have had

Table 4: Examples of Learning in ISD

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