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Measuring design process agility for the single company product development process

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This paper seeks to explore the way in which agility across the product development process may be measured using a previously defined measure of agility: Key Agility Index. It is a fact that very few companies keep accurate records of project timings and the delays caused by unpredictable events. The classification of unexpected events for two case studies is explored, based on a previously defined classification system of trivial; minor; major and fatal events. The case studies show how empirical qualitative data regarding project timings and unexpected events can be gathered through expert interview and can be used with the Key Agility Index to provide a realistic and practical measure of agility.

Keywords: Agility, Measurement, Performance Metrics, Expert Interview, Qualitative Data

1. Introduction

The majority of businesses in the 21st century are operating in highly volatile and turbulent environments, be they manufacturing companies or service providers. In order to succeed they must be flexible and continuously evolve [1]. Volume flexibility, extreme customisation and rapid responsiveness are seen as order winning criteria [2]. Agility has been described as one way in which this turbulent external environment can be managed and there has been much research in recent years focussing on the benefits to manufacturing of an agile production process. This has included re-configurable machines, factory layouts and manufacturing processes. The benefits of agility in the manufacture of products are well documented, and recent research has also explored the application of agile methodologies from the manufacturing process to other aspects of the product development cycle. There have also been numerous attempts to define ways in which the agility of a manufacturing process or a whole business might be measured (see Section 3).

This paper seeks to explore the application of a measure of agility known as the Key Agility Index (KAI), proposed by Pay [3], which overcomes the requirement for gathering large amounts of data which can be expensive and is often unattainable. The remainder of this paper is structured as follows: Section 2 details the background to the research including other agility measures. Section 3 will then present the KAI proposed by Pay, and Section 4 will introduce the industrial case studies which were carried out for two different projects. Section 5 will discuss the findings of the case studies and application of the agility measure to the empirical data gathered. Finally, Section 6 will conclude the paper and recommend further research along this theme.

2. Background

Agile Manufacturing was first introduced at Lacocca Institute, Lehigh University in 1991. Since then there have been many attempts to define agility, and definitions have varied depending on the context to which the authors are relating the concept, i.e. local machine level agility or global enterprise level agility.

A common definition of agility is the ability to respond successfully and rapidly to change in the climate of an unpredictable external environment. However this does not consider the use of previous experiences to anticipate change and act pro-actively [4]. Goldman et al. [5] identified four key dimensions of agility: Delivering value to the customer; Being ready for change; Valuing human knowledge and skills; and Forming virtual partnerships. These virtual partnerships are a distinguishing feature of agile manufacturing [6], allowing companies to concentrate on core competences and re-configure their alliances with other companies to align their overall enterprise with the continually changing requirements.

Gunasekaran [7] defines agility as 'the capability of surviving and prospering in the competitive environment of continuous and unpredictable change by reacting quickly and effectively to chosen markets, driven by customer-designed products and services'. There exist many more definitions, but all acknowledge the importance of a rapid response in an unpredictable business environment. The unpredictable environment has been classified in a number of ways, including into four levels of external event [17]:

- Trivial – can be dealt with locally
- Minor – requires external assistance
- Major – a partner must be replaced
- Fatal – the design is no longer valid and the project must be re-started

Each level of event has a more significant effect (causes a larger penalty) on the overall project. This may not always be on the timing of the project but could be translated into a cost or quality penalty.

Ramasesh et al. [10] classify unanticipated changes into three categories:

- Output-related change – changes in demand
- Input-related change – changes in materials
- Process-related change – changes to technology or environmental regulations

Yauch et al. [11] identify 8 sources of environmental turbulence:

- Customers
- Suppliers
- Competitors
- Government Agencies
- Corporate Patent
- Other divisions or plants within the same corporation
- Technology
- Other outside forces

The agile organisation can therefore be described by Figure 1, where Corporate Patent is included as 'Other Outside Forces' and 'Corporation' refers to other divisions or plants within the same corporation.

3. Measuring Agility

The plethora of definitions, many of which focus on issues such as 'customer satisfaction'; 'surviving and prospering'; and 'valuing' make it difficult to apply a measure of agility to suit each definition, as measures rely on quantitative data such as timings and yields sales.

One theme for the measurement of agility is the level of adoption of a number of key criteria for an 'agile enterprise' i.e. a company that has adopted more of the key attributes is 'more agile'. Yusuf et al. [9] define 32 key attributes in 10 decision domains for an agile manufacturing enterprise, while Ren et al [12] propose a requirement for six agility attributes:

- Speed
- Proactivity
- Flexibility
- Cost
- Quality
- Innovation

An alternative method of agility measurement is a more quantitative approach, rather than attainment of a set of attributes. A hybrid approach is the use of questionnaires for company managers to ascertain the level of adoption of each of a set of attributes. The attributes are weighted based on contribution to overall agility and therefore a score can be obtained. Kassim and Zain [13], and Sharifi and Zhang [14] both propose methods adopting this strategy. Kumar and Motwani [8] propose a methodology for assessing time-based competitive advantage, but again through the use of a self-assessed survey. Giachetti et al. [15] use the measurement of structural properties of the business rather than operational properties for assessing agility, i.e. the information and material flows, organisational relationships and communication networks instead of batch sizes, change-over time, etc. Giachettie and Arteta [4] propose the assessment of a firm's complexity is directly related to its agility, and that backward looking assessments (in terms of time) do not suggest how a company may behave in the future to further unpredictable events.

Rameshash et al. [10] suggest a quantitative framework to explore the value of agility in financial terms, the Net Present Value of all relevant cash flows being the measure of agility. Another quantitative approach is that of Yauch [11], defining the measure of agility as the ability to succeed in a turbulent environment. The agility score is derived from organisational success (financial performance from public data) and the level of environmental turbulence for that market sector (determined by experts).
The majority of these methods rely on data gathered by questionnaire, meaning that the data used will be the opinion of whoever completes the questionnaire, not necessarily the person best placed to do so. For existing quantitative methods, the level of data is often too detailed and the level of data required is inaccessible or even not recorded by the company.

The agility measure proposed uses expert interview to obtain course timing data relating to a particular project. This level of course data is usually available through interview of the correct staff, overcoming the concerns of the availability/reliability of more detailed data. It also allows a more useful measure for individual companies at an operational level than the use of global, publicly available data for entire organisations.

Youssef et al [16] argue that agility 'should not be equated just with speed of doing things, for it goes far

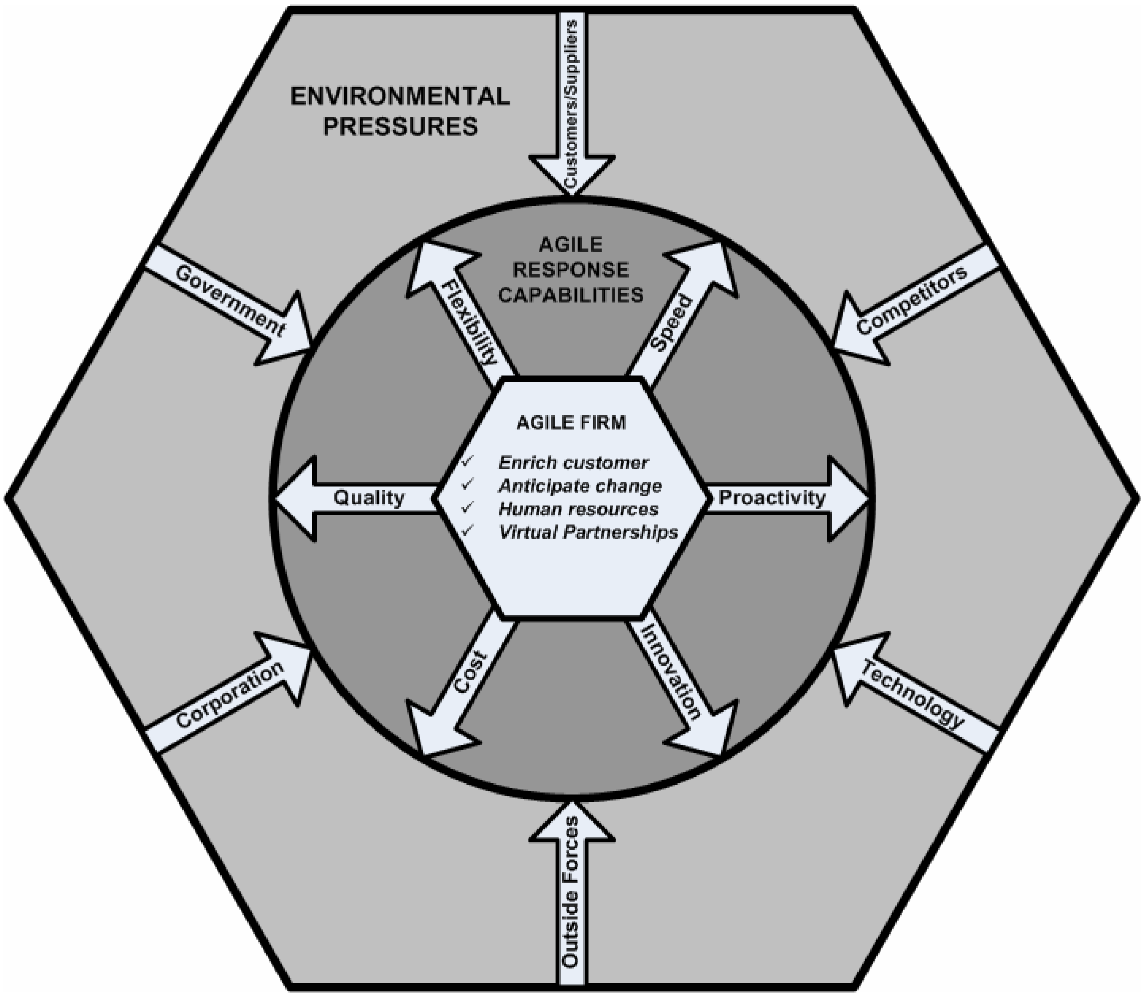

Figure 1 - The Agile Organisation

beyond speed', however, Ran et al. [12], in ranking the effect of agile attributes on competitive priorities rank speed as the most important, followed by: Pro-activity; Flexibility; Cost; Quality; Innovation. The measure proposed utilise timing data, but does not simply look at 'speed of doing things', rather what the timings say about the responses to unpredictable events in the environment.

The data required for the measure is course timing data which is normally available, specifically:

- Time spent on Scheduled Tasks.
- Time spent on Change Related Tasks – these are tasks which were not scheduled but were necessary as a direct result of an unpredictable external event (UEE).

This level of data can be easily gathered through expert interview.

3.1. Key Agility Index

The Key Agility Index (KAI) is defined as the ratio of: Time taken to complete Change Related Tasks and Time taken to complete the whole project. The KAI gives a measure of the proportion of project time spent completing Change Related tasks, i.e. responding to UEEs. Reducing the time-response to UEEs results in a reduction in KAI. By presenting the KAI as a ratio, it allows a comparison between projects within a company and between companies in a similar sector.
The KAI can be used across the total Product Development Cycle, or it can be used for specific stages of the process to assess agility within the manufacturing stage, the design stage, etc.

Companies operating in different sectors and/or markets should not use the KAI for direct comparison as it does not take account of the inherent turbulence of particular sectors. For example, the IT sector is very turbulent with

ID	Task Name	Start	Finish	Duration
1	Fit Rolling Chassis Components	06/02/2006	10/02/2006	1w
2	Fit Cab	13/02/2006	17/02/2006	1w
3	Fit Body	13/02/2006	17/02/2006	1w
4	Finishing	20/02/2006	24/02/2006	1w
5	Testing	27/02/2006	03/03/2006	1w
6	Redesign Handbrake	06/03/2006	08/03/2006	3d
7	Order Parts	08/03/2006	10/03/2006	3d
8	Design Brackets	09/03/2006	10/03/2006	2d
9	Fit Handbrake	13/03/2006	13/03/2006	1d
10	Test Handbrake	14/03/2006	15/03/2006	2d
11	Redesign Handbrake	14/03/2006	16/03/2006	2d
12	Order Parts	16/03/2006	21/03/2006	3d
13	Design Brackets	16/03/2006	17/03/2006	1d
14	Fit Handbrake	22/03/2006	22/03/2006	1d
15	Test Handbrake	23/03/2006	23/03/2006	1d
16	Adjust Handbrake	24/03/2006	24/03/2006	1d

Figure 2 - Project Timings for Electric Vehicle Manufacture

high consumer expectation, advanced and ever-evolving technology, high government interest and many more factors. Therefore this sector is inherently unpredictable. By contrast, the manufacture of furniture or hand-tools is inherently stable, with materials and designs varying only slightly from year to year. In order to make a comparison between these two sectors, a further variable should be introduced to the equation which would account for the inherent turbulence of the environment and normalise the results. However this analysis of market sectors is outside the scope of this paper.

4. Industrial Case Studies

The company with whom the agility assessment was made was a manufacturer of service vehicles. The assessment was carried out on two different projects within the company, allowing an internal comparison to be made between projects. Project 1 concerns the *manufacture* of an electric recycling vehicle commissioned by a local council. The Scheduled project time for manufacture was 20 days from the start of assembly to completion of testing. However during testing it became evident that the handbrake design was not valid for the design requirements. To resolve this event the handbrake module was re-designed and re-

ID	Task Name	Start	Finish	Duration
1	Design process	05/12/2005	16/12/2005	2w
2	Order parts from Bill of Materials	19/12/2005	13/01/2006	4w
3	Dwell Time awaiting chassis	16/01/2006	10/02/2006	4w
4	Fit Chassis and Cab	13/02/2006	24/02/2006	2w
5	Fit running gear	27/02/2006	03/03/2006	1w
6	Finishing	06/03/2006	10/03/2006	1w
7	Testing	13/03/2006	24/03/2006	2w

Figure 3 - Project Timings for Aircraft Service Tug Design and Manufacture

tested twice before a valid design was found, causing a time-penalty to the manufacture of 15 days. The project timings can be seen in Figure 2.

This event can be assessed through the time-penalty caused as shown below, and also according to the classification system described earlier. The validation failure of the handbrake design was a *minor* event, meaning that the event could be dealt with internally, and no further assistance was required from outside (specialist skills or knowledge).

The project timings were gathered through a short interviewing the project manager. The benefit of this method is that it does not impose too heavily in the time of the managers, but it does allow course timing data and information regarding unpredicted events to be gathered for a useful assessment of the firm's agility for a given project.

The KAI can be calculated as:

$$KAI = \frac{T_C}{T_S} = \frac{15}{35} = 0.429$$

Project 2 involves the *partial design* and *manufacture* of an Aircraft Service Tug. The estimated delivery date from the receipt of order was 10 weeks, however the actual delivery date was 16 weeks. The project began with a re-design of some components to satisfy a change in the requirements from the customer upon ordering the tug. Once complete, the project was divided between a number of collaborating agents. The second delay was caused by the failure of one agent to satisfy their requirements for delivery of one component. This was an agent located on the critical path of the project and so the delay caused a knock-on effect of four weeks delay.

The KAI for Project 2 can be calculated as:

$$KAI = \frac{T_C}{T_S} = \frac{6}{16} = 0.375$$

Using the classification system of four levels of unpredictable external event, the re-design and the delay of the delivery of part of the project were minor events, as they could be handled internally. If, in the case of the failure of an agent to deliver their part of the project on-time, a replacement partner had been required to complete that task instead, then the classification would move to major and a more significant penalty would be incurred.

5. Discussion

The value of KAI = 0.375 indicates a more agile process for Project 2 than for Project 1, because a smaller proportion of the total project time was spent on Change Related Tasks. This Key Agility Index provides a mechanism for acquiring a quantitative measure of agility from a short interview with key staff, eliminating the need for detailed questionnaires and data collection, but providing a measure at the useful project level.

When fed back to companies this measure alongside details of the causes of Change Related Tasks can allow companies to address the way in which they are able to react to these unpredictable events. For Project 1 the event was a validation failure of the design, leading to two iterations of re-design and testing before a valid solution could be found. Clearly invalid designs are not part of any agile process and the Key Agility Index for Project 1 reflects this. By assessing the KAI, the project managers can see the extent of the impact on the project and seek to identify improvements to the validation procedure for the next project. Project 2 had two separate events, a design change from the customer and a delay in delivery from one collaborator on the critical path. However despite the two events the KAI suggests that the project was more agile because it was able to deal with the events in a timelier manner. The case studies presented here only deal with events which have a direct impact on the critical path of the project. Further research must address the impact of time-penalties occurred locally without a global effect. If companies can keep all their UEEs off the critical path does this make them more agile?

6. Conclusions

The paper has discussed existing methods for agility assessment and has identified that they often require a detailed analysis of organisational attributes gathered via questionnaire or timings of projects which are often too detailed and unavailable without significant effort. The Key Agility Index offers a means of acquiring a quantitative measure of agility through brief empirical data collection with key personnel. The measure has been tested in industry and it was found that the data was easily available in a short period and that although tested on short projects with few UEEs, the measure was quickly calculable and provided useful feedback on the agility of each project. The events in the two case studies were all classified as *minor*, and the agility levels of the two projects were also similar, although one is seen to be more agile than the other. Further work may identify a correlation between the UEE classifications and the corresponding Key Agility Index.

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8. Biographies

Chris Lomas graduated from Durham University in 2003 with a Masters degree in Engineering (Manufacturing and Management). He is a PhD candidate and his research interest relates to Agile Design.

Jeremy Wilkinson is an MEng Candidate at Durham University. His thesis research relates to time-based frameworks for the assessment of agility in design and manufacturing organisations.

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Peter Matthews took a PhD in the application of AI tools at the University of Cambridge. He is now a Lecturer at the School of Engineering, Durham University.