Lead Times and Soft Factors

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Abstract

This paper presents a study of the influence of and the relationship between lead times and soft factors in large software development projects. Soft factors are used as a collective term for factors that are hard to quantify exactly, i.e. non-technical aspects. Data has been collected for 12 projects. The lead times have been recorded together with a grade in the range 1-5 for 10 soft factors. The grading is based on a subjectively made judgement from project reports and by talking to the project managers etc. The ten soft factors are then divided into three groups based on their identified influence on the relationship lead time / log(man-hours). The division of the factors into three groups is the basis for proposing a scheme for calculating a soft factor goodness figure for each project. The proposal is based on 4 of the projects. The goodness figure is then evaluated on the other 8 projects. The projects are divided into 3 classes based on the lead times normalized with log(man-hours), i.e. slow, normal and fast projects. It is shown that there is a clear correlation between the goodness figure and the actual lead times / log(man-hours). It can be concluded that by calculating a goodness figure it will be possible to plan and control the lead times. A scheme is proposed from which, based on the goodness figure, it is possible to determine which type of project it is likely to be, i.e. a slow, normal or fast project. It is believed that this approach can be further refined in the future and that the proposed scheme will be a helpful method for the software engineers and managers to handle lead times and soft factors.

List of keywords

Metrics, lead times, productivity, soft factors

1. INTRODUCTION

To overcome the prevailing problems of error management, missed deadlines and overspent budgets, commercial software developers will have to embrace the concept of 'measuring' projects. The latter includes all aspects of a software project, e.g. processes, methods, tools, organizations and in particular humans. The area of software metrics has been studied extensively during the last decade, e.g. (Conte et al. 1986, Fenton 1991).

Many of the studies are related to tools, methods, languages etc. and their influence on for example fault content and code size. Some work has also been done in the area of productivity, (Boehm 1981, Jones 1986, Jones 1991). Most of the productivity work has been concerned with technical issues and not much work has been made on the soft aspects. The humans and other 'hard to quantify aspects' are central in the development process, but these are very difficult factors to cope with. In the rest of the paper, all of these factors are collected in the term soft factors. The term is used to describe factors that are very difficult (at least today) to measure and quantify without relying on judgement. It is easy to let go of the soft factors because of the quantifying problems, but this will be a big mistake. These factors have to be studied and quantified carefully. The perhaps most well-known work has been done by Boehm. It has, however, been shown that even if the productivity is ten-folded the gain in project development times (i.e. lead times) is much less, somewhere in between 2-3.

The objective with the work, presented in this paper, is to study and quantify the impact of soft factors on the lead times. In particular, the soft factors relate to aspects that are different in different projects, even though the organizations work with the same type of applications and have the same technical basis. The soft factors studied are further discussed below.

It is believed and emphasized in several software projects today that it is more important to have short lead times than to have an optimal productivity. The reason is, of course, that it is more economic to find the market window, than to minimize the costs during development. This does not mean that the productivity is unimportant, on the contrary. If it comes to a trade-off between productivity and lead time, it is often the case that the lead time has a higher priority, since it is important to be first on the market. This motivates that we would like to emphasize the lead time rather than the productivity.

The soft factors are studied due to the conviction, which is supported by the studies presented in (Boehm 1981, Boehm 1987), that the outermost important part to achieve the goals of a software project is the soft factors.

The study results in a proposed method for planning and controlling the soft factors to master the lead times, instead of being ruled by them. We believe that the method will become a valuable asset in mastering the lead times for software projects. It will be possible, depending on the requirements on lead times, to put constraints on the soft factors. The manager must be able to state the requirements on personnel, priority compared to other projects, the necessary requirement stability etc. to be able to fulfil the lead time requirements whatever they are.

2. PROJECT DATA

This paper presents an investigation of the influence of and the relationship between lead times and soft factors in large software development projects. The study is based upon 12 projects carried out between 1987-1989.

For the 12 projects, the lead times have been recorded together with a grade in the range 1-5 for 10 soft factors. The grading is based on a subjectively made judgement from project reports and by talking to the project managers etc. The grade 5 means that the factor is judged to have been very good, i.e. in comparison of what one could expect in a fast project. As an example, the hypothesis is that high competence gives a fast project, which means that if the project is staffed with people having very high competence the grade will equal 5. A fast project is characterized by a low value on lead time / log(man-hours). This means that the lead time is normalized with the man-power.

The ten soft factors investigated are:

- competence
- product complexity
- requirement stability
- staff turnover
- geographical distribution of the organization
- methods and tools
- time pressure
- information flow
- priority
- project management

The actual choice of these ten factors is based both on other investigations in the literature, e.g. (Boehm 1981, Boehm 1987) and experience from earlier projects within the organizations being studied.

Data from the 12 projects are presented in table 1. The ten factors have been graded from 1 to 5 in the projects.

Factor \ Project	1	2	3	4	5	6A	6B	7A	7B	8A	8B	9	10	11	12
Competence	3.5	3	4	2	3	3	3	4	3	2	2	3	2.5	4	3
Product complexity	2	2	1	3	4	-	2	-	1	-	2	2	3	5	1
Requirement stability	3	4	2	3	1	3	4	2	4	4	1	4.5	2.5	1	2
Staff turnover	3	3	4	2	3	3	1	4	1	3	2	5	3	2	2
Geographical distribution	1	2	1	1	3	2	2	2	1	1	1	1.5	2	5	1
Methods and tools	2.5	2.5	2	2	3	3	3	3	3	3	2	2	3	2	3
Time pressure	4.5	5	-	5	2	3	3	4	4	3	3	3	3.5	3	3
Information flow	4.5	4	3	4	2	-	3	-	4	3	2	4	4.5	3	3
Priority	4	1	3	5	2	3	3	3	3	3	2	4	3.5	3	3
Project management	4.5	3	3	5	2	2	3	3	4	2	3	4	4	4	4

Table 1: Project data for the 12 projects included in the study

It must be noted that there are two different judgements concerning project 6-8. The first one, A, is made through studying the project reports written after the projects were finished, while B is made directly by the project leaders who participated in the projects. The differences between A and B for these projects are interesting, but not surprising. It only shows how difficult it is to put grades on these soft factors. The A columns are based on the judgement made by the same person who has judged the other projects as well.

It is hard to determine whether the A columns or the B columns shall be used as 'the right figures'. The main advantage by choosing the A columns is that the judgement has been made by the same person for all projects. This means that there may be a systematic error, but probably no random errors. The judgement ought to be fair when comparing the projects. The judgement presented in B is better in the sense that the project leaders ought to know best, since they actually made the development. It was unfortunately impossible to obtain a B estimate for all 12 projects.

It has, however, been noted over and over that the organization performing project 6-8 seems to be very critical in terms of high demands on quality etc. They have a good record in successful projects and they usually perform better than other similar organizations. This could indicate that they may put a lower grade than would have been done if the same project had been run in another organization.

All in all, it just shows how difficult it is to put grades on these factors. The judgement of people on these factors are bound to be different and it only shows the necessity to formulate good rules of what constitutes the grades for a specific factor. Another soft factor is the maturity of the development process. Some work in the area of formulating rules for grading the maturity of software processes are presented in (Paulk et al. 1991).

The conclusion from this reasoning is that today we have to accept that different organizations will make different judgements, mainly based on prior experience. It can also be concluded that until good rules exist it would be best if each organization make its own quantification of the soft factors.

The objective with this study is to try to draw some general conclusions. This can only be done if the conclusions are based on all projects. It is impossible in this investigation to study the separate organizations, since the number of projects at the different organizations is too small. This motivates why the results presented mainly will be based on the grades presented in the A columns. The results presented below would, however, probable be improved if it would have been possible to study just one organization. Unfortunately, the data available did not permit this.

3. THE RELATIVE INFLUENCE OF THE SOFT FACTORS

The 12 projects are plotted in a diagram according to their lead times and log(man-hours), figure 1.

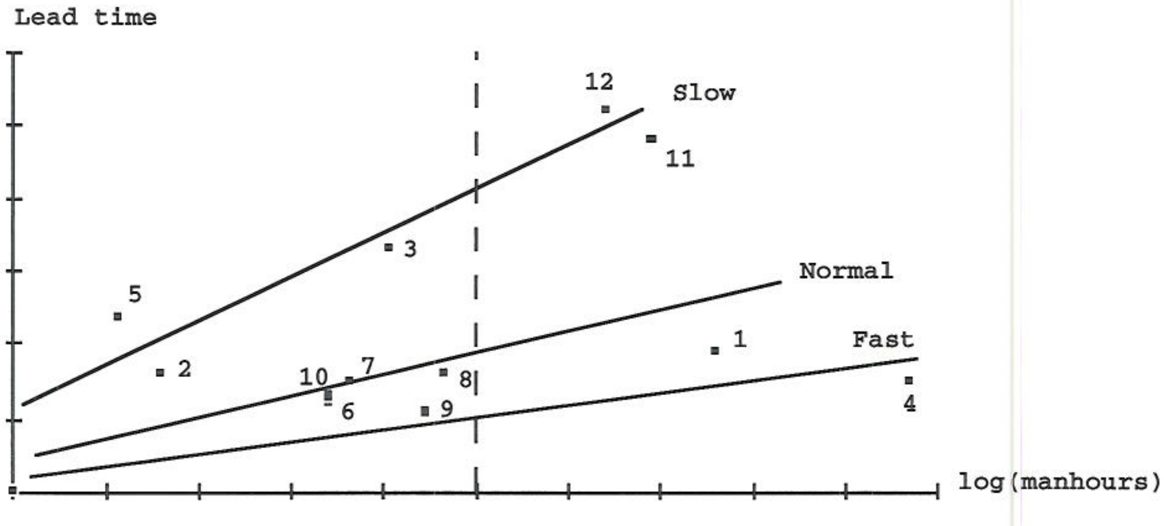

Figure 1: The relationship between log(man-hours) and lead times for the 12 projects

It is known, from earlier studies, that the relationship between lead time and man-hours is unlinear (Boehm 1981, Kitchenham 1987), that is why log(man-hours) is used. Figure 1 contains three lines representing; fast, normal and slow projects respectively. A fast project is characterized by a low value of the division lead time / log(man-hours), which is a process measure, indicating whether the efficiency is high or low.

From a table of the lead times and the man-hours of projects, two fast and two slow projects were chosen. The objective was to try to identify the impact of the soft factors on the lead times. We identified projects 3 and 5 as being slow and projects 1 and 4 as being fast. The soft factors characterizing the two types of projects (fast and slow) were identified, see table 2. As an example it can be seen in table 2 for "project management" that projects 1 and 4 are graded 4.5 and 5 and the projects 3 and 5 are graded 3 and 2, thus indicating that project management influences the quotient lead time / log(man-hours).

Factor \ Project	1	3	4	5
Competence	3.5	4	2	3
Product complexity	2	1	3	4
Requirement stability	3	2	3	1
Staff turnover	3	4	2	3
Geographical distribution	1	1	1	3
Methods and tools	2.5	2	2	3
Time pressure	4.5	-	5	2
Information flow	4.5	3	4	2
Priority	4	3	5	2
Project management	4.5	3	5	2

Table 2: Project data for the "fast" projects (shaded) and the "slow" projects

Unfortunately the number of projects is somewhat small, but some trends were identified, i.e. some factors were identified having a greater influence on the lead time / log(man-hours) than others. According to these trends the soft factors were divided into three groups:

- **Influence identified:** There is a difference between fast and slow projects and the difference is supported by intuition.
- **Influence identified, but the trend is debatable** A weak pattern was identified, but the pattern did not fit the intuition.
- **No influence identified:** There is no difference between fast and slow projects.

According to this the soft factors were grouped as follows.:

- **Influence identified:**
  - Requirement stability
  - Time pressure
  - Information flow
  - Priority
  - Project management
- **Influence identified, but the trend is debatable**
  - Competence
  - Staff turnover
- **No influence identified:**
  - Product complexity
  - Geographical distribution of the organization
  - Methods and tools

In the group "influence identified" the influence is supported by the intuition, but the soft factors in the other groups need to be commented upon.

- **Competence:** Intuitively the competence should be affecting the lead time, but the figures only partly support this theory. It would be absurd to conclude that competent personnel would imply slow projects, but It might be that competence has a higher influence upon man-hours than upon lead time, and thus making the quotient high. Another explanation is that difficult projects are staffed with highly skilled personnel, making it look like competence does not influence the lead time.
- **Staff turnover:** Intuitively the staff turnover should be affecting the lead time, but it might be that staff turnover has a higher influence upon man-hours than upon lead time.
- **Product complexity:** This may be coupled to the problem with competence discussed above. It is likely that people with high competence is assigned to the most difficult projects.
- **Geographical distribution of the organization:** Considering that the distributed units are having well-specified tasks of which they are fully responsible, it is of no surprise that the impact on the lead time is low. The projects are able to run very much in parallel.
- **Methods and tools:** The change in methods and tools over time is a slow process and they are therefore very similar for the different projects. Over a period of 10 years the differences are big, but within a year the differences are quite small.

Multiple linear regression was applied, but the small amount of projects made it very hard to come to any conclusions. The correlation between the soft factors was run and also the correlation between the soft factors and lead time / log(man-hours). These results are presented in section 6.

4. THE POTENTIAL OF THE SOFT FACTORS

The potential of the soft factors is to improve the ability of the organization to produce fast projects often and by controlling the soft factors avoiding sub-optimisation. This implies that slow and normal projects could turn into fast ones. When studying the three lines in figure 1 the variations between fast, normal and slow projects are large. An example, where the dashed line is the difference between a normal and a fast project is 1.6 times and the difference between a fast and a slow project is 4.0 times. These differences between the different groups of projects vary due to the project size, which is realised when looking at figure 1. The calculation shows that there is a great potential of improvement in the soft factors, which must be utilized in the future by managing the soft factors efficiently. This means for example using the soft factors as a basis for decision making, i.e. the most important activity must be given the highest priority regarding the soft factors. In particular, this means that it can be controlled which projects that will be fast etc.

The potential of the soft factors is not limited to lead time, other quality attributes such as productivity and fault content (Lennselius 1990) are also affected. This implies that a soft factor might have a positive impact on one quality attribute, but not on another. There is a great potential in using the soft factors to control the characteristics of a project.

5. QUANTIFICATION OF THE SOFT FACTORS

5.1 Calculation of Q-figure

The grouping of the soft factors led to the assignment of numbers to the three groups as follows. The numbers will be referred to as *significance figures*.

- **Influence identified:** 3 (important factors)
- **Influence identified, but the trend is debatable:** 2 (these factors influence the lead time, but since the influence disagree with the intuition they have obtained a lower *significance figure*)

- **No influence identified:** 1 (even though no influence is identified we believe them to be of some significance to the lead time, otherwise they would not have been considered when doing this investigation)

To be able to plan and control projects regarding the soft factors, the effect of the soft factors must be quantified. This implies that it must be possible to calculate a figure that tells us whether we will get a fast project or not. We propose that a soft factor goodness figure (Q-figure) shall be calculated. This is done in the following way:

1. Multiply the grade of the soft factor (1-5; according to the assigned numbers) by its *significance figure* (1-3; according to the grouping of the soft factors).
2. Sum up for all of the soft factors being graded, the calculations in item 1
3. Divide the sum-up by the number of factors being graded (in our case maximal 10 factors). The Q-figure is hereby obtained.

This figure tells us how good the soft factors are in a specific project. The following Q-figures are obtained in the 12 projects:

Project	1	2	3	4	5	6A	6B	7A	7B	8A	8B	9	10	11	12
Q-figure	8.0	6.9	5.9	8.0	4.9	6.3	6.3	7.1	7.0	6.6	4.6	8.0	7.3	6.6	6.0

Table 3: Q-figures for the 12 projects in the study

A high value though meaning that the lead time is short in relation to log(man-hours) Since the *significance figures* are based upon projects 1, 3, 4 and 5 it is of no wonder that those projects fit smoothly to this model, i.e. 1 (8.0) and 4 (8.0) have obtained high values and 3 (5.9) and 5 (4.9) have obtained low values. The interesting part is to evaluate to what extent the remaining projects fit into the goodness figure model.

Project 9 has obtained a high goodness figure (8.0), which indicates that it ought to be a fast project. According to figure 1, where the lead time / log(man-hours) relationship is plotted, project 9 is very fast (even faster than project 1). Projects 7 (7.1) and 8 (6.6) being normal projects and project 12 (6.0) being a slow project also fit very well into the model.

Also projects 6 (6.3) and 10 (7.3) support the model, though if the model would have been perfect project 6 and 10 would have obtained somewhat higher goodness figures.

The two slow projects 2 (6.9) and 11 (6.6) though have received too high goodness figures. A conclusion worth stressing is that the model did not point out any project as being neither slower nor faster than the projects forming the basis for the model (1, 3, 4 and 5). One project, number 9, did receive a goodness figure as high as projects 1 and 4, but this is explained by project 9 being as fast as the other two..

It must also be stressed that the last conclusion is on condition that judgement A is used for projects 6 through 8, since the B variant of project 8 has an extremely low goodness figure.

In an attempt to correlate the Q-figure by the quotient lead time / log(man-hours) the correlation turned out to be -0.75 in the "A-case" and -0.54 in the "B-case". The minus-sign indicates that a high Q-figure gives a low value of the quotient, i.e. a fast project, which is as expected. The first-mentioned correlation is rather good, i.e. it is close to -1.0. The great difference between A and B shows how much the result depends upon a single project, since the difference is very much due to project number 8. This indicates mainly two things: the importance of having impartial grades, i.e. grades that make it possible to compare projects, and the importance of an enlarged study including a greater number of projects.

The results seem promising, especially since it is the first study being done. This model could provide us with an instrument helping us to use the potential in the soft factors to produce fast projects. In particular, we can control which projects that will be slow and fast respectively. Further investigations will be needed but the first seed is sown.

5.2 Project classification

The goodness figures make it possible to group the projects according to slow, normal and fast projects. An attempt to classify the projects according to the goodness figures could be done as follows:

- Slow projects: 2.2 <= Q-figure <= 6.0
- Normal projects: 6.0 < Q-figure <= 7.5
- Fast projects: 7.5 < Q-figure <= 11

The lower limit (2.2) as well as the higher limit (11) are calculated from that the factors being 1 and 5 respectively and that all 10 factors are being assessed.

The definition above implies that the 12 projects will be grouped as follows:

- Slow projects: 3, 5, 12
- Normal projects: 2, 6, 7, 8, 10, 11
- Fast projects: 1, 4, 9

It is possible to identify that the outcome of this classification corresponds very well to how the projects are placed in figure 1. As noted earlier projects 2 and 11 ought to have been in the group "slow projects", but also note that according to figure 1 none of the two has a higher value of lead time / log(man-hours) than any of the "slow projects".

The three lines in figure 1 can be used together with the Q-figure to make predictions of the lead time or the number of man-hours or to decide the necessary value of the Q-figure to be able to achieve certain demands on lead time or man-hours, see section 7.1.

6. CORRELATION BETWEEN SOFT FACTORS

It would be naive to believe that the soft factors affect the quotient lead time / log(man-hours) independently. In this model these aspects are not taken into consideration, but in an integrated model the correlation between the soft factors must be included. Nevertheless it is interesting to study both how the soft factors are correlated, to increase understanding of the problem domain, and how the soft factors are correlated to lead time / log(man-hours). The latter is done to investigate to what degree it supports our choice of *significance figures*. The correlations obtained, which are accounted for in table 4, are based upon data from assessment A (projects 6 - 8). The results from the correlation of data from assessment B though do not imply any great differences.

The interpretation should be done as follows: High correlation is implied by a figure that is close to the absolute value of 1, i.e. -1 and 1 meaning totally correlated. A minus sign implies that there is a reverse correlation, i.e. when the value of one of the two factors is high the other one is low. An example: "geographical distribution" is correlated to "product complexity" by 0.86, meaning that they are highly correlated.

Note that there is a danger in drawing conclusions from separate correlations since it is a complex of correlations, e.g. good project management is aimed at in high priority projects, which give rise to a good information flow, which depends upon...and so on.

Factor \ Factor		1	2	3	4	5	6	7	8	9	10
Competence	1										
Product compl.	2	-0.01									
Req. stab.	3	-0.50	-0.49								
Staff turnover	4	0.28	-0.38	0.39							
Geograph. distr.	5	0.40	0.86	-0.56	-0.25						
Method; tools	6	-0.23	-0.04	-0.11	-0.13	-0.10					
Time press.	7	-0.08	-0.33	0.39	-0.12	-0.37	-0.36				
Info. flow	8	-0.19	-0.25	0.58	0.14	-0.34	-0.22	0.74			
Priority	9	-0.24	-0.03	0.14	-0.01	-0.33	0.36	0.19	0.43		
Project man.	10	-0.02	-0.06	0.04	-0.23	-0.11	0.54	0.52	0.67	0.66	
Lead t. / Log (mh)		0.44	0.07	-0.70	-0.34	0.40	0.02	-0.48	-0.75	-0.46	-0.15

Table 4: Correlation table

The correlations between the soft factors and lead time / log(man-hours) support the groups identified earlier. The four factors with the highest correlations are found within the *"influence identified"* group and the two factors with the lowest correlations are found in the *"no influence identified"* group. The correlation of two factors in the *"influence identified, but..."* group are found in between. There are two exceptions though. The soft factor "project management" grouped into *influence identified"* , turn out to have a low correlation (-0.18), and "geographical distribution..." grouped into *"no influence identified"* , has a rather high correlation (0.40). "Project management" though is highly correlated to both "information flow" and "priority" in the *"influence identified"* group, which support that also "project management" ought to be there. A similar way of reasoning is done for "geographical distribution".

The highest correlations found between the factors are the following:

- product complexity - geographical distribution 0.86
- time pressure - information flow 0.74
- project management - information flow 0.67
- priority - project management 0.66

These results are not very surprising. The most interesting is that "time pressure" and "information flow" are highly correlated, implying that time pressure enforces you to have good information flow in order to fulfil your obligations.

The most surprising result is concerning competence. There is no correlation between "competence" and "product complexity" (-0.01). This somewhat astonishing results might depend upon the relative nature of competence. If a person is put on a simple task he/she is considered being competent, but if the same person is put on a more difficult task he/she might not be competent at all.

It must also be pointed out that "staff turnover" does not seem to correlate with any other soft factor.

7. SOFT FACTORS IN PRACTICE

7.1 Soft factors today

The soft factors would be an important input to project management especially in project planning. In using the soft factors for these purposes, the first thing to do is to draw the three lines (slow, normal and fast), as shown in figure 1, based upon knowledge from earlier projects. The two possible ways to use the diagram are, as described briefly above:

1. *Either the man-hours or the lead time is known (via demands or estimation):* In this case different ways to reach the demand/estimate will be evaluated, i.e. the Q-figure can be used as a steering parameter in controlling either the man-hours or the lead time. An example: A project is estimated to require a certain amount of man-hours. The three lines give us the possibility to, depending on the requirements on the lead time, control whether the project is to be fast, normal or slow. The organization is able to manage the soft factors in order to obtain a Q-figure making the project fit into the "correct" line.

2. *The soft factors, i.e. the Q-figure, are known:* An estimate of the quotient lead time / log(man-hours) is obtained, since the Q-figure decides what line to use. By determining the lead time or the number of man-hours and since the Q-figure is known, the other one can be obtained.

This implies that the three main activities are performed in different order due to which application is used, i.e. the activities: calculation of Q-figure, determination of type of project (slow, normal and fast) and graphical evaluation.

The steps we believe an organization must take to implement this scheme for managing the soft factors are described as follows:

Introduction: The first thing one should do is to put effort in creating an organization that is capable of controlling the soft factors to obtain predictable lead times in software projects as well as turn projects into fast projects. By using diagrams, as the one in figure 1, it is possible to build up a corporate understanding of the impact of soft factors and to create faster projects by focusing on relevant factors. It is important that each organization creates its own diagram and identify relevant soft factors. The following steps ought to be followed:

- identify soft factors that are believed to be relevant
- define measures according to the soft factors
- measure soft factors, lead time and man-hours
- plot a diagram where lead time relates to log(man-hours), identify fast, normal and slow projects and draw their lines
- identify the impact of the soft factors, group them according to whether they influence the project or not and assign numbers to them
- calculate goodness figures and identify the characteristics of each group.

Maintenance: Secondly this programme requires to be maintained to be kept up to date. The following tasks are very important:

- measure lead time and log(man-hours) and update the diagram. It is very important to identify the evolution of the organization, i.e. after some time the lead time / log(man-hours) relationship hopefully have improved. This implies that new lines must be drawn in the diagram.
- measure the soft factors to improve the grouping of them and improving the *significance figures* as well as the goodness figures.
- identify new soft factors that are found being important and old ones that do not seem to fit (anymore), and update the soft factors according to this.

7.2 Future possibilities

This investigation is a first, but nevertheless a promising attempt, to control the impact of the soft factors on software development projects. This implies that there is more important and interesting work to be done, before understanding and being able to control the total complex of the soft factors.

Development: In the future one would like to control the projects independently of the three lines, i.e. for all points in the plane. As mentioned before the relationship between lead time and man-hours is unlinear. This could be expressed as follows: *Lead time = a * (man-hours**b).* This formula is supported by earlier studies and a and b have also been quantified (Boehm 1981, Jones 1977 and Walston-Felix 1977). It is not as simple as to "steal" the formula out of literature, a and b have to be derived from the organization where they are supposed to be used.

A line drawn according to this formula would represent a "normal" project. The soft factors give the possibility to run the projects in a way that is more or less favourable to the lead time, thus making the project diverge from the "normal" project. A model taking this divergence into account should be developed, thus making it possible to predict the outcome independently of the three lines. The following could be an objective for future development:

1. Calculate the lead time or man-hours in a "normal" project according to *Lead time = a * (man-hours**b).*
2. Calculate the lead time taking the soft factors into account. A formula, based upon the lead time relationship in item 1 and the soft factors, having the following general appearance might be used: *Lead time (new) = f(k1sf1, ksf2,...lead time (normal)).* k1, k2 etc. are constants that weigh the influence of a specific soft factor, i.e. a further development of the *significance figures.* sf1, sf2 etc. are the quantified soft factors.

The advantage of making predictions using mathematical expressions is, when having the expressions, not being locked to a certain selection of outcomes. The drawbacks are that it is not simple to produce the mathematical formulas and that it is difficult for the persons doing the predictions to intuitively know what they are doing.

8. CONCLUSIONS

The 12 projects give a good picture of the importance of the soft factors. The introduction of a goodness figure would be a possible way to study the influence of the soft factors on the lead times and by this classify the projects in slow, normal and fast respectively. This forms the basis for being able to plan and control the soft factors in software projects to come. Time critical projects can obtain a good mixture of the soft factors to provide a good basis for fulfilling the time constraints, i.e. the required lead time. The high demands on short lead times mean that it is necessary to have a method for controlling the soft factors. These factors can not be left uncontrolled in the future. The organizations developing software must apply metrics on soft factors to be able to control them as proposed in this paper. The measurement of soft factors is difficult, but nevertheless worth while.

The area is relatively new and much still remains to be done, but the work done so far is inspiring for the future. It is believed that this approach can be further refined in the future and that the proposed scheme will be a helpful method for the software engineers and managers to handle lead times and soft factors.

9. ACKNOWLEDGEMENT

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10. REFERENCES

(Boehm 1981) Boehm, Barry, "Software Engineering Economics", Prentice-Hall, Englewood Cliffs, N.J., USA, 1981.

(Boehm 1987) Boehm, Barry, "Improving Software Productivity", IEEE Computer, September 1987, pp. 43-57.

(Conte et al. 1986) Conte, S. D., Dunsmore, H. E. and Shen, V. Y., "Software Engineering Metrics and Models", Benjamin/Cummings, Menlo Park, California, USA, 1986.

(Fenton 1991) Fenton, Norman, "Software Metrics: A Rigorous Approach", Chapman & Hall, London, Great Britain, 1991.

(Jones 1977) Jones, T.C., "Program Quality and Programmer Productivity", IBM TR 02.764, 28 January 1977.

(Jones 1986) Jones, Capers, "Programming Productivity", McGraw-Hill, New York, USA, 1986.

(Jones 1991) Jones, Capers, "Applied Software Measurement", McGraw-Hill, New York, USA, 1991.

(Kitchenham 1987) Kitchenham B., "Management Metrics" in "Software Reliability - Achievement and Assessment" edited by Littlewood B., Blackwell Scientific Publications, 1987.

(Lennselius 1990) Lennselius Bo and Rydström Lars, "Software Fault Content and Reliability estimations for Telecommunication Systems", IEEE Journal on Selected Areas in Communications. Vol. 8. No 2, February 1990, pp. 262 - 272.

(Paulk et al. 1991) Paulk, Mark C., Curtis, Bill and Chrissis, Mary Beth, "Capability Maturity Model for Software", Software Engineering Institute, Report: CMU/SEI-91-TR-24, Pittsburgh, Pennsylvania, USA, 1991.

(Walston-Felix 1977) Walston C.E. and Felix C.P., "A Method of Programming Measurement and Estimation", IBM Syst. J., 16, 1, 1977, pp. 54 - 73.