Packaging Software Process Improvement Issues – A Method and a Case Study

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Summary

Software process improvement is a challenge in general and in particular for small and medium sized companies. Assessment is one important step in improvement. However, given that a list of improvement issues has been derived, it is often very important to be able to prioritize the improvement proposals and also look at the potential dependencies between them. This paper comes from an industrial need to enable prioritization of improvement proposals and to identify their dependencies. The need was identified in a small and medium sized software development company. Based on the need, a method for prioritization and identification of dependencies of improvement proposals was developed. The prioritization part of the method is based on a multi-decision criteria method and the dependencies are identified using a dependency graph. The developed method has been successfully applied in the company, where people with different roles applied the method. The paper presents both the method as such and the successful application of it. It is concluded that the method worked as a means for prioritization and identification of dependencies. Moreover, the method also allowed the employees to discuss and reason about the improvement actions to be taken in a structured and systematic way.

Key Words

Software Process Improvement, Prioritization, Dependency Mapping, Packaging, Decision Support, Small and Medium Sized Enterprise, Industrial Case Study

1. Introduction

The production of high quality software with a limited amount of resources, and within a certain period, is the goal of most software producing organizations. They vary from large corporations with thousands of engineers, to small ones with only a handful. All of them, regardless of location, size or even success-rate, are largely dependent on their software *processes* [1] to reach their goals.

It stands to reason that continuous evaluation and improvement of an existing process (Software Process Improvement - SPI [1]) is crucial to ensure that the organization is successful in its pursuits of quality, and in order to be effective enough to stay competitive in the world of business.

The work presented in this paper introduces a structured way in which software development practitioners (whose organization is subject to SPI efforts), and SPI practitioners alike, can make dependency adherent prioritizations of identified improvement issues (findings from process assessments). The goal is to give small and medium sized enterprises (SMEs) a tool to focus their SPI efforts, and not to present "yet another method" as such. The work presented here should complement already existing SPI frameworks with a modular addition intended to minimize some of the main issues with SPI efforts identified in literature (see Section 2.1).

The paper is structured as follows. Section 2 gives some background information pertaining to SPI concerns and the motivation behind the work presented in this paper. Section 3 introduces the "Dependency Adherent Improvement Issue Prioritization Scheme" or "DAIIPS" for short, and the techniques on which it stands. Section 4 presents a study using DAIIPS in an industry SPI effort. The results from the industry study are subsequently validated through an additional study performed in academia, and the results from the two studies are compared for validation purposes. Section 5 has the discussion and the conclusions.

2. SPI – Related Work and Motivation

An SPI scheme is usually based in four fairly straightforward steps, "evaluation of the current situation", "plan for improvement", "implement the improvements", "evaluate the effect of the improvements", and then the work takes another cycle (see Figure 1, inspired by [2]).

[1] A sequence of steps performed for the purpose of producing the software in question (IEEE-STD-610).

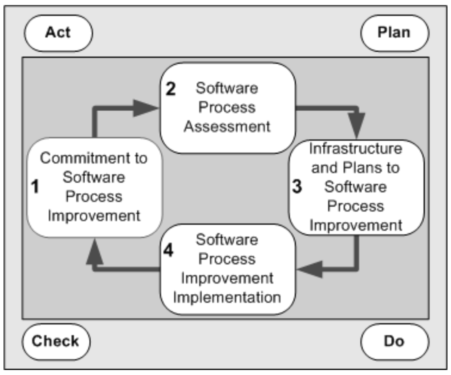

Act
Plan
2 Software Process Assessment
1 Commitment to Software Process Improvement
3 Infrastructure and Plans to Software Process Improvement
4 Software Process Improvement Implementation
Check
Do

Figure 1. Generic Process Improvement Scheme.

Most well known process improvement (quality improvement/assurance) frameworks are based on this general principle. From the Shewart–Deming "Plan-Do-Check-Act" paradigm [3] and Basili's "Quality Improvement Paradigm" [4], to standards like CMM [5], CMMI,[6] ISO/IEC 15504 (a.k.a. SPICE) [7] and the Software Engineering Institutes IDEAL SPI Guide [8].

Looking at the frameworks mentioned above (primarily CMMI, CMM, SPICE and IDEAL) they have been used for SPI over a number of years (except for CMMI) and there are quite a lot experiences reported from industry.

The main issues seem to be *cost* and *time*. An assessment-improvement cycle is often rather expensive and time consuming [9]. A typical SPI cycle using e.g. CMM can take anything from 18 to 24 months to complete [10] and demand much resources and long-time commitments in order to be successful. In addition to being time consuming many view extensive SPI frameworks as too large and bulky to get an overview of and to implement [2, 11, 12].

However, this is not the same as saying that frameworks like e.g. CMMI are inapplicable in general. Organizations with time and resources available report high return on their investment over an extended time period (results indicate both lower costs and higher customer satisfaction) [2, 11]. The main issue here is rather whether or not a small and medium sized enterprise (SME) has the ability to commit to a large-scale SPI project spanning over a long time period as far as the work and pay-off is concerned.

There are examples of attempts to adapt larger SPI frameworks to be more suitable for SMEs. The IMPACT project [13] reports an initiative to use elements from proven technologies like CMMI and SPICE to implement a lightweight SPI framework. Another example is presented in [14] where IDEAL is adjusted for use in SMEs. The work presented in this paper is meant to add to this effort of making SPI available for SMEs.

2.1. SPI Concerns and DAIIPS Goals

In addition to the factors mentioned above, that may have a negative impact on SPI efforts (pertaining mainly to SMEs) i.e. (I) Time (long-term work, long-term gain) and (II) Cost/Resources (the nature of large SPI frameworks imply commitment of much resources over an extended period of time), there are a number of more general critical aspects (not directly linked to SMEs) presented in literature [15] [16] [17] [18] [19].

Some of the central are[2] (III) Commitment (to the SPI effort by management, middle management and the staff e.g. engineers), (IV) Focus (on the SPI effort with clear and well-defined goals) and (V) Involvement (in the SPI work by staff).

If we look at DAIIPS the first and foremost motivation for the development of the framework was to give organizations with limited resources for SPI a chance to choose *what to do first* based on their needs.

The need for this was first recognized in relation to cooperative SPI work conducted at DanaherMotion Särö AB (see Section 4), a medium sized company about to undertake process assessment and process improvement work of their requirements engineering process. With limited resources available it was crucial that the improvements be manageable in size and time, thus not posing a threat against their core activities (the business of producing income generating products).

The idea was to prioritize and package improvement issues in smaller and more manageable groups based on how important they were to the organization, and the dependencies between the improvement issues. This division of a potentially large amount of improvement issues (depending on what was found during the

[2] In addition to these there are other factors that influence the success of SPI activities. However these are not elaborated upon here due to the fact that they are out of the scope of this paper.

software process assessment phase) was to help organizations take small steps towards quality improvement at a manageable rate and with a realistic scope. This addresses the factors of (I) time, smaller packages of improvement issues can be implemented and evaluated faster (the results are felt in the organization sooner rather than later), and (II) cost/resources in terms of smaller steps each costs less and large resources do not have to be committed over long periods of time. By dividing a potentially large amount of improvement issues into smaller packages for implementation one could argue that it is easier to define clear and manageable goals for the SPI activities, e.g. results lie closer in time and there are a limited number of issues that are addressed (speaking of aspect IV). Many SPI efforts fail before they start, i.e. an assessment is made, then the work stops and no real improvements are made. A lack of follow-thorough is usual, and this may be contributed to several of the reasons mentioned above, of which commitment of time and resources are not the least [9]. This is the motivation behind DAIIPS, to offer SMEs a framework to choose what to do, i.e. limit the commitment to a manageable level.

DAIIPS is directly dependent on the involvement, contribution and expertise of the personnel involved in the SPI activity, namely a selection of representatives from the organization (as are most SPI paradigms). This is the nature of DAIIPS, i.e. all the decisions (regarding priority and dependencies) are made by the people working with the current process in the organization. The direct nature of the involvement in the work and decision-making speaks to securing the SPI work in the minds of the very people that the SPI activities influence the most, i.e. relating to aspects III and IV.

DAIIPS is not an absolute method, which should be followed to the letter, rather a framework for gathering data in a certain way, formatting it and presenting the results in way that should ultimately act as decision support for SPI activities.

2.2. DAIIPS and Modularity

As mentioned earlier DAIIPS is not meant to compete with any SPI model, in fact DAIIPS is just a structured way to prioritize and check dependencies amongst the improvement issues already identified using a software process assessment (SPA) tool, e.g. CMM, CMMI, SPICE or IDEAL. Thus, the prerequisite for using DAIIPS is that an assessment has been made and that the improvement issues are documented and explained in such a way that the constituents of the SPI targeted organization can understand them. Given this restriction almost any assessment framework/standard/method can be used, including lightweight methods [20].

3. DAIIPS – An Overview

DAIIPS consists of three basic steps, (A) prioritization, (B) dependency mapping, and (C) packaging (illustrated in Figure 2). Steps A and B are performed in sequence at a workshop, while step C is performed at a later stage.

As mentioned earlier improvement issues identified during the SPA stage of the SPI effort are used as input. Each of the steps is described in further detail below.

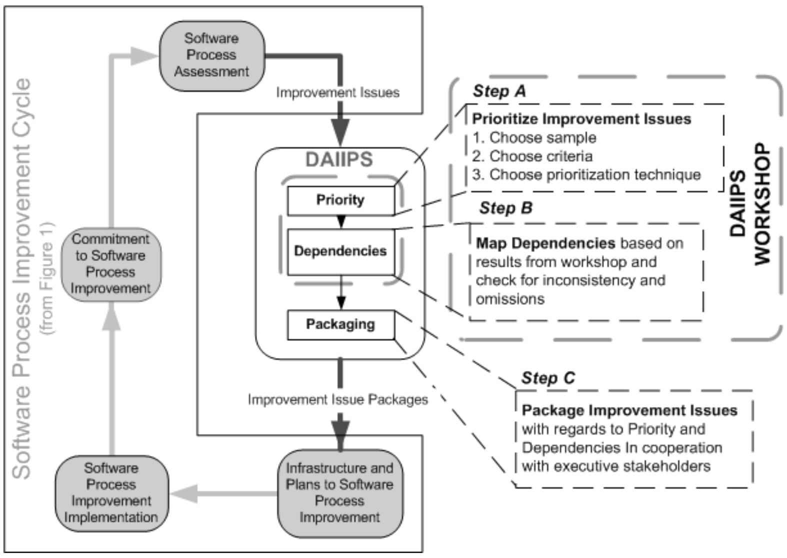

Software Process Improvement Cycle
(from Figure 1)
Software Process Assessment
Improvement Issues
DAIIPS
Priority
Dependencies
Packaging
Commitment to Software Process Improvement
Improvement Issue Packages
Software Process Improvement Implementation
Infrastructure and Plans to Software Process Improvement
Step A
Prioritize Improvement Issues
1. Choose sample
2. Choose criteria
3. Choose prioritization technique
Step B
Map Dependencies based on results from workshop and check for inconsistency and omissions
DAIIPS WORKSHOP
Step C
Package Improvement Issues with regards to Priority and Dependencies In cooperation with executive stakeholders

Figure 2. DAIIPS Overview.

3.1. Prioritization (Step A)

The idea behind prioritization of the improvement issues in DAIIPS is to introduce an explicit choice amongst the issues identified during assessment, i.e. all improvement issues are channeled into the prioritization unordered and with no "importance" attributes attached after the assessment. A number of sub-steps should be performed in prioritization (see Figure 2), each described below.

For an example of the prioritization (Step A) and results from an industry case, see Section 4.3.2.

3.1.1. Sample

There should be a conscious decision behind the choice of what stakeholders should be invited to participate in the prioritization step. The sample could be based on a sampling technique, what technique depends on applicability in the case at hand. One alternative could be to invite all of the participants of the SPA performed earlier (if this is a manageable number of people). The participants of the SPA should have been selected in line with some plan (although this cannot be assumed). However, if the SPA sample is deemed good-enough it can be reused, saving time both in regards to selecting the sample and introducing the sampled subjects to the SPI activity. There are quite a lot of sampling techniques available, see e.g. [21] [22] for examples.

The sample size is also important and once again it should be possible to look at the sample size used during the SPA. A main issue is to get a sample large enough making it possible to generalize, i.e. a large variability in the population (typical for a software development organization) demands a larger sample.

Quota sampling and Stratified random sampling [21] are both based on having elements (strata/groups) from which a representation is wanted, e.g. programmers, middle management, testers and so on.

Through sampling certain views (agendas) could be premiered over others, i.e. by having an overrepresentation of a certain group (role) in the sample. An example of this could be having an overrepresentation of developers – thus adding weight to their influence on the prioritization.

Despite of how the sampling is conducted it should be a conscious action with regard to the consequences it may have on the prioritization.

For an example of sampling performed in an industry case, see Section 4.2.1.1.

3.1.2. Criteria

There are characteristics of the process that we want either to minimize or to maximize. Quality, time, cost and risk are three examples of criteria. When prioritizing improvement issues it is done in relation to a criterion. If quality is the criterion (improve/maximize quality) the prioritization will be skewed in one direction, if time is the criterion other aspects may be more important. Which criterion is chosen must be up the SPA team (including management), and should be based on strategic goals of the organization subject to the SPI as well as the findings of the SPA.

The choice of criteria should be conveyed to the participants beforehand (and consensus reached about what a criterion means) in order for the prioritization to be done with the same focus in mind.

For an example of criteria formulation in an industry case, see Section 4.2.1.1.

3.1.3. Prioritization Techniques

Several techniques can be used for the prioritization of improvement issues. The main idea is to have a structured way in which prioritization can be performed in the same manner (technique) and with the same intent (criterion) by all participants. Furthermore the results from the prioritization should be comparable to each other, this to enable a compilation of the results.

In this paper we briefly present one prioritization method used in our study (see Section 4), and mention three more. Note that AHP is just one of several available prioritization techniques that may be used.

The Analytical Hierarchy Process (AHP) [23] is a method using scaled pair-wise comparisons between variables, as illustrated in Figure 3.

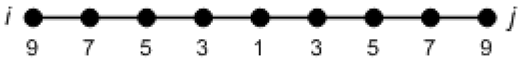


Figure 3. AHP Comparison Scale

Here the variables are ***i*** and ***j*** and the scale between them denotes relative importance. The importance ratings can be seen in Table 1 below.

Table 1. AHP Comparison Scale

Relative intensity	**Definition**	**Explanation**
1	Of equal importance	The two variables (*i* and *j*) are of equal importance.
3	Slightly more important	One variable is slightly more important than the other.
5	Highly more important	One variable is highly more important than the other.
7	Very highly more important	One variable is very highly more important than the other.
9	Extremely more important	One variable is extremely more important than the other.
2, 4, 6, 8	Intermediate values	Used when compromising between the other numbers.
Reciprocal	If variable *i* has one of the above numbers assigned to it when compared with variable *j*, then *j* has the value 1/number assigned to it when compared with *i*. More formally **if $n_{ij} = x$ then $n_{ji} = 1/x$**.	

As the variables have been compared the comparisons are transferred into an ***n x n*** matrix with their reciprocal values (***n*** is the number of variables). Subsequently the eigenvector of the matrix is computed. The method used for this is called *averaging over normalized column* and the product is the *priority vector,* which is the main output of using AHP for pair-wise comparisons.

AHP uses more comparisons than necessary, i.e. ***n x (n – 1) / 2*** comparisons, and this is used for calculating the consistency of the comparisons. By looking at the *consistency ratio (CR)* an indication of the amount of inconsistent and contradictory comparisons can be obtained. In general a CR of ≤ 0.10 is considered to be acceptable according to Saaty [23], but a CR of > 0.10 is often obtained. There has been some debate as to the applicability of results that have a CR of > 0.10, see [24] and [25], and this is an ongoing debate. A rule of thumb is that a CR of ≤ 0.10 is optimal, although higher results are often obtained in the real world. Further details about AHP can be found in [23] and [26].

AHP Example (Using AHP to prioritize mobile phone features)

answer	**feature**																		**feature**
1	SMS	**9**	+	**7**	+	**5**	+	[✓ **3**]	+	**(1)**	+	**3**	+	**5**	+	**7**	+	**9**	Color display
2	SMS	**9**	+	**7**	+	**5**	+	**3**	+	**(1)**	+	**3**	+	[✓ **5**]	+	**7**	+	**9**	WAP
3	SMS	**9**	+	**7**	+	**5**	+	**3**	+	**(1)**	[✓ +]	**3**	+	**5**	+	**7**	+	**9**	Vibrating Call Alert
4	WAP	**9**	+	**7**	+	**5**	+	**3**	+	**(1)**	+	[✓ **3**]	+	**5**	+	**7**	+	**9**	Color display
5	WAP	**9**	+	**7**	+	**5**	+	**3**	+	**(1)**	+	**3**	+	[✓ **5**]	+	**7**	+	**9**	Vibrating Call Alert
6	Vibrating Call Alert	**9**	+	**7**	+	[✓ **5**]	+	**3**	+	**(1)**	+	**3**	+	**5**	+	**7**	+	**9**	Color display

Having 4 features *[n=4]* to prioritize against each other would demand a table with 4 x (4 - 1) / 2 = 6 rows *[n x (n – 1) / 2],* i.e. require 6 answers in order to complete the AHP prioritization. Note that all features are compared to each other once. (The answers in our example are denoted by the black circles)
The CR (consistency ratio) comes from how consistent the answers are in comparison to each other, e.g. in the example above (answer 1) "SMS" is considered slightly more important than "Color display", (answer 2) "WAP" is considered highly more important than "SMS". The inconsistency comes in (answer 4) when "Color display" is considered slightly more important than "WAP". A consistent answer would be that "WAP" was more important than "Color display".
The more inconsistent answers, like in the example above, the higher the CR will be for the prioritization.

The CR from the prioritization above is 0.19, which is well above the recommended limit proposed by Saaty. This example shows that a high inconsistency (i.e. CR > 0.10) is not especially difficult to obtain with only a few variables to prioritize, not to mention if you have e.g. 10 variables (10 variables means 45 prioritizations). The positive thing is that the CR actually indicates consistency, which can be seen as a quality indicator of a person's answers.

The Planning Game is a more informal way in which the improvement issues can be sorted and ordered according to priority. This method is used extensively in extreme programming [27] for feature and release planning, but can easily be used in prioritizing improvement issues.

Ranking involves putting the improvement issues in a list; where the higher in the list an issue is the more important it is deemed and vice versa. The result of this ranking is a list of ordered issues on an ordinal scale (it is possible to observe that e.g. issue ***I*** is more important than ***J*** but not how much more important it is).

The "100-points method" can be used to distribute tokens of some sort (e.g. "money") amongst the issues. The issues are prioritized with regards to how much "money" they receive. An example of this could be to give each person doing the prioritization \$100 (or \$1000 etc) to distribute amongst the improvement issues. The result from this method is a weighted prioritization on a ratio scale (the issues are ordered and a distance between them can be observed, e.g. issue ***I*** is \$10 more important than ***J***). For further information see [28].

The primary goal with prioritization is to ascertain what improvement issues are considered important, and which can be put off for future SPI cycles. The choice of technique depends on e.g. how many issues you have to prioritize. AHP demands ***n x (n – 1) / 2*** comparisons, e.g. 45 comparisons for 10 issues. This amount is manageable, but when considering 20 issues (190 comparisons) it may start to get unmanageable. To get e.g. 10 professionals to sit down and do 190 comparisons (and be consistent) is not easy. Using the 100-point method and giving them the task of distributing \$100 over the 20 issues may be more feasible in this case.

It is important however to realize that different prioritization methods have different pros and cons, e.g. AHP gives information about consistency and relative priority, whereas e.g. the planning game does not but is much faster in performing when dealing with many improvement issues. A comparison of prioritization techniques is provided in [29].

3.1.4. Weighing the Priorities After the Fact

As each contributor's results are gathered there is the possibility to weight the results, and hence enabling to decide on the importance of a certain viewpoint. An example of this could be a desire to premiere developers and their views by multiplying their results by 1.0, while using the multiplier of 0.6 for e.g. managers, effectively premiering one view over another. This is the same as discussed in Section 3.1.1, where the sample selection was as a weighting method, but this could also be done after the prioritization, independent of sample.

The danger of adding weights is evident, i.e. it could initiate conflicts, as well as belittle valuable views. The possibility of weighting results exists independent of prioritization technique used, but should only be performed after careful consideration, and with clear reasons.

3.2. Mapping Dependencies (Step B)

This step is aimed at mapping the dependencies between improvement issues. For an example of results obtained during a dependency mapping performed industry, see Section 4.3.3.

This step should involve the same participants as the prioritization (given that the prioritization participants were sampled from the organization in an adequate manner, see Section 3.1.1). Some variations may be necessary, i.e. being able to prioritize issues is not the same as being able to identify dependencies between them. Whether or not the prioritization sample can be reused depends largely on the constituents of the sample itself, i.e. what people are involved, where they work (department) and what their competences are. Identified dependencies are drawn (by each participant) between the issues with two major attributes registered, i.e. *direction* and *motivation*. The arrow itself denotes a dependency between two issues, e.g. ***I-B*** and ***I-A*** as illustrated in Figure 4, and the direction of the dependency can be seen through the direction of the arrow. In Figure 4 issue ***I-B*** depends on ***I-A*** (as does ***I-C***).

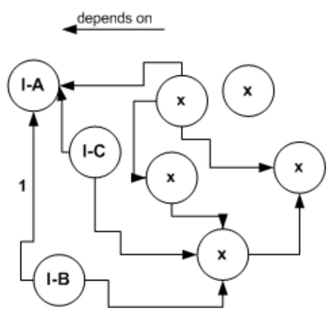


Figure 4. Dependency Diagram Example

> **Dependency Example**
>
> A real life example of a potential dependency could be if there were two new practices to be introduced into an organization, e.g. *Programming in Java* and *Object Oriented Design*. Java is an object oriented programming language, therefore the practice of *Object Oriented Design* should be implemented first (to make use of Java as an object-oriented programming language), i.e. *Programming in Java* is dependent on having an *Object Oriented Design*. If this example is transferred to Figure 4 *Object Oriented Design* could be denoted by ***I-A*** and *Programming in Java* could be denoted by ***I-B***. The dependency is denoted by the arrow (1).
>
> The motivation could in this case be "there is no point in introducing an OO programming language if we cannot design in an OO fashion…"

In addition to drawing the arrows a *motivation* for each arrow is registered. This is done to avoid arbitrary and vague dependencies and dependencies can be sorted and compared during the compilation of the results, i.e. it is possible to see if two participants have the same type of dependency between two issues, or if the same arrow denotes two different views. This is also a way in which different types (views) of dependencies can be elicited.

The result of this step should be a list of dependencies between the issues as well as their relative weight, i.e. how many times they are specified by the participants. Table 2 illustrates the results of an example dependency mapping. The dependencies present (e.g. I-B on I-A) is decided by what dependencies are identified. P 1, P 2, …, and P *n* denote the participants, and the numbers in each participant's row denotes if he/she stated the dependency or not (1 for YES). By summarizing the number of identifications of a certain dependency weights are ascertained. In this case I-B on I-A has a weight of 4, I-B on I-C has 3, and so on.

The weights are compiled and drawn into a dependency diagram, see Figure 5, which is like the one presented earlier in Figure 4, but with the addition of weights, and "white" issues (I-D and I-F) denoting issues that have no dependencies on them. Note that issue ***I-F*** has no dependencies on it, and furthermore is not dependent on any other issue either.

Table 2. Dependency Table

Dependency	P 1	P 2	P 3	P 4	P *n*
I-B on I-A	1	1	1	1	
I-B on I-C	1	1		1	
I-C on I-A		1		1	
I-C on I-E		1			
I-D on I-B	1	1	1		
I-*n* on I-*n*					

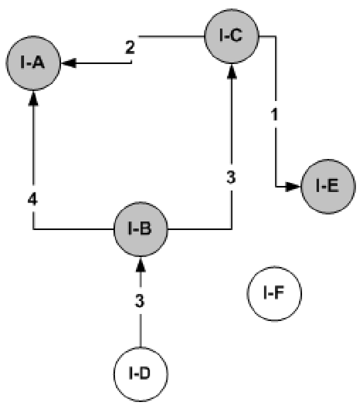


Figure 5. Dependencies with Weights

If an improvement issue dependency has a low weight, e.g. 1 (***I-C*** on ***I-E*** in Figure 5 has a weight of 1), *one* person has only identified the dependency. Such single occurrences may be a result of misunderstandings and/or other anomalies (given that e.g. 10 persons participate in the dependency mapping) and can be omitted to avoid having a great number of weak dependencies to take into consideration. However, all "anomalies" should be scrutinized by the SPI group before they are dismissed in order to assure that the dependency is not relevant. The SPI group should not dismiss dependencies unless a consensus can be reached about the issue.

A good rule of thumb is that there should be a "threshold" set by the SPI group beforehand. The idea with mapping dependencies is to catch the important relations between improvement issues. Too many dependencies amongst a large number of issues can result in a dependency diagram that is unmanageable, and thereby useless. On what level this threshold should reside should be governed by the circumstances of the dependency mapping occurrence.

3.3. Package Improvement Issues (Step C)

Thus far, we have the priority of the improvement issues, and a mapping of the dependencies amongst them. The last stage of DAIIPS is to compile the information in order to generate packages of improvement issues that can be used as a base for planning and implementing an SPI cycle.

For an example of improvement issue packaging in an industry case, see Section 4.3.4.

Figure 6 is a continuation of our example from previous sections with all information gathered in one figure. The improvement issues ***I-A*** through ***I-F*** are augmented with relative priority (denoted by the number within parenthesis) and relations with weights. The larger numeral (upper left hand in each circle) denotes the rank of each improvement issue, i.e. ***I-C*** has the highest priority and ***I-D*** the lowest (note that all priority methods do not produce relative values of priorities, AHP is used in this example, see Section 3.1.3).

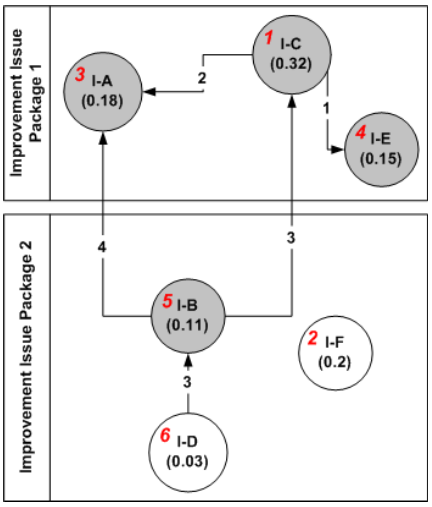


Figure 6. Improvement Issue Packages

The packaging of the issues largely depends on what is entailed in each improvement issue. In our simple exemplification all issues demand equal time and resources to implement, thus the division of them into two packages is fairly simple. ***I-C*** is of highest priority, i.e. it governs that ***I-A*** and ***I-E*** be packaged with it due to dependencies on these two issues. Observe that issue ***I-F*** that is the second issue in relative priority is not included in package 1, i.e. the relations have precedence over priority in this example.

Priority, *dependencies* and *cost* (estimated resources demanded for implementation) are the primary variables that have to be adhered to during packaging. The packaging should be done to reflect the current and near-future needs of the organization (*priority*) as well as the available resources for process improvement (attention to *cost*), and last but not least attention should be paid to the order (*dependencies*) of the implementation of improvement issues. It seems that packaging one issue that cannot be realized until another is implemented, e.g. packaging issue ***I-A*** in package 2 in our example would be less than optimal. This is not to say that dependencies always should take precedence over the other variables. There are more ways in which the packaging can be performed, which is chosen is up to the SPI group. The main concern in this step is to package the issues so that a compromise between priority, dependencies and cost can be reached as the issues are packaged into units that are appropriate for an SPI cycle. The SPI group decides this with the individual improvement issues as a base, i.e. an initial estimation and planning has to be done to ascertain what each improvement issue will entail as far as time and resources are concerned. In the example above the division is simple, which may not be the case in reality. Diagrams (like the one displayed in Figure 6) should act as a decision support tool for the SPI group when undertaking the task of establishing what is to be done first, second and so on.

As the three steps are completed the SPI group needs to perform a validity review. This should be an official action performed to ascertain that (1) the results from the prioritization and dependency mapping are good enough to proceed, and (2) a formal review of the documentation produced to ascertain that no omissions/mistakes crept in during the processing of the data gathered from the DAIIPS work. Reviews of dismissed dependencies (e.g. was the threshold set at a proper level), and to what extent is high inconsistency (CR) a threat against the ascertained priority of the improvement issues are examples of important issues. This validity review should help ensure that the quality of the material produced through the usage of DAIIPS is high.

4. Industry and Academia Study

This section presents the design and results of the industry and academia (validation) study performed in order to test the DAIIPS framework in an industry setting. The section is structured as follows. Sub-section 4.2 the designs of the studies are described. The results from the industry study are presented in Sub-sections 4.3.2 (Step A), 4.3.3 (Step B), and 4.3.4 (Step C), corresponding to DAIIPS three major steps (see Figure 2). Section 4.4 presents the academia (validation) study results, and in Sub-section 4.5 the industry and academia study are compared in a validation attempt.

The industry study described in this paper is from a SPI project performed at DanaherMotion Särö AB (DHR), where the use of DAIIPS was a part of the SPI work.

DHR develops and sells software and hardware equipment for navigation, control, fleet management and service for Automated Guided Vehicle (AGV) systems. More than 50 AGV system suppliers worldwide are using DHR technologies and know-how together with their own products in effective transport and logistic solutions to various markets worldwide. The headquarters and R & D Centre is located in Särö, south of Gothenburg, Sweden. DHR has 85 employees. DHR is certified according to SS-EN ISO 9001:1994 (currently working on certification according to ISO 9001:2000), but there have not been any attempts towards CMM or CMMI certification.

DHR has a wide product portfolio, as the ability to offer partners and customers a wide selection of general variants of hardware and supporting software is regarded as important. Tailoring and especially lighter customer adaptation often follows the procurement and subsequent installation of a system. This in addition to development of new software and hardware makes it a necessity to plan, execute and manage a wide range of projects.

4.1. Related work

The need for continuous process improvement is well known at DHR. They identified the area of requirements engineering as a good candidate for improvement work. This paper (the DAIIPS framework and the industry study presented below) is a product of research conducted at DHR based on their need for improvements in their requirements engineering process. Although DAIIPS was formulated in conjunction with requirements engineering process improvement work, it is not tailored towards a single sub-process area (e.g. requirements engineering), but can be used in any process and/or sub-process improvement effort.

A proceeding process assessment concentrated on the area of requirements engineering was conducted at DHR using a lightweight triangulation approach [20].

The nine improvement issues (see Section 4.3) used as input to DAIIPS (as viewed in Table 5) came from this assessment of the requirements engineering process at DHR.

4.2. Study Design

This section covers the design of the industry study performed. The design is based on the DAIIPS steps described in Section 3, and can be seen as the preparation for the use of DAIIPS.

In addition to performing a study in industry a second study was performed in academia. The academia study's purpose was to validate some of the results obtained in the industry study, e.g. an effort to secure the external validity of the study (see Section 4.2.3.3), and to help in increasing the confidence that no important dependencies were missed during the industry study, i.e. the use of DAIIPS in an industry SPI effort. An overview of the studies is illustrated in Figure 7. Improvement issues (obtained during process assessment) are used as input for DAIIPS used in the two studies. Observe than only the dependency mapping was performed during the academia study, as the prioritization results (see Section 4.4) were not used.

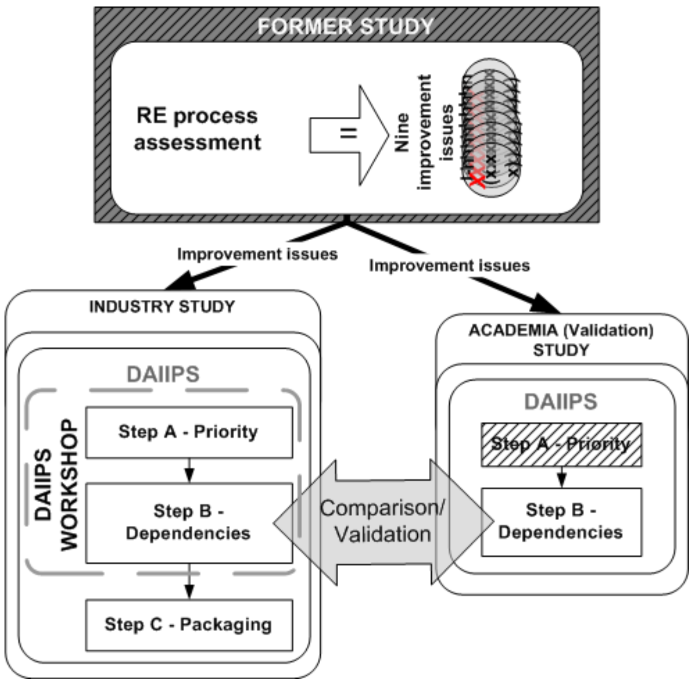


Figure 7. Study Overview

4.2.1. Industry Study Design (Preparation Step A and B)

4.2.1.1 Prioritization Preparation (Step A)

Sampling (see Section 3.1.1) of the subjects for the prioritization (and later the dependency mapping) was based on the sample selected for the process assessment (PA) conducted (as mentioned in Section 4.1). It was based on quota sampling, in an effort to get subjects from different parts of the population [21]. The quotas were selected based on ten different roles identified in development at DHR:

1. The *Orderer* has the task of being the internal owner of a certain project, i.e. has the customer role and if applicable the official contact with an external customer and/or partner. This party is responsible for the official signing-off when it comes to the requirements, i.e. he/she places an order.
2. The *Project Manager* has the traditional role of managing the project, resources, planning and follow-up. As far as requirements are concerned the Project Manager is responsible for that the requirements engineering is performed, the requirements specification is written and signed off by the System Engineer.
3. The *System Engineer* is the technical responsible for a project. It is also important to recognize that the System Engineer has the official responsibility for the requirements specification in a project.
4. The *Developer* is a representative for the developers (e.g. programmers) in a project, the ones actually implementing the requirements. The developers use the requirements specification.
5. *The System Test* role can be described as the traditional role of application and feature test. This role is officially present during initial project meetings and is a part of the verification of the requirements specification.
6. *The Production* role also has a presence in projects. This representation consists of verifying that the production aspects are met, i.e. that production is taken into consideration at an early stage.
7. *The Application Developer* role represents installation and adaptation aimed at industry partners and/or end customers. Adaptation here translates to tailoring, development of some light customer features and some support.

In addition to having representatives for the roles presented above three more general roles were represented:

8. *Management*
9. *Sales/Marketing*
10. *Sales Support*

The last three roles were more general in nature in comparison to the development specific roles presented before. In total 14 people participated distributed over the roles as can be viewed in Table 3.

Table 3. Participant Distribution over Roles - Prioritization

Role	No. participants		Role	No. participants
1	1		6	1
2	2		7	1
3	2		8	2
4	2		9	1
5	1		10	1

The reason for having ten roles and 14 participants (i.e. an overrepresentation of some roles) was twofold. First the overrepresented roles housed most senior personnel and it was deemed positive to maximize the amount of senior staff participating. The second reason was executive, i.e. the roles of Project managers and System engineers to a degree represented the (in this study) undefined role of middle management.

Criteria (see Section 3.1.2) were based on maximizing the quality of the produced products in terms of customer satisfaction. The focus was to increase the quality of the requirements engineering process, thus meeting the objective of increasing customer satisfaction.

Prioritization technique (see Section 3.1.3) was chosen because there were only nine improvement issues to prioritize. With this in mind AHP was suitable, and could provide priority and information about e.g. consistency (see Section 3.1.3 – AHP for further information), and [29] for a evaluation of AHP in comparison to other prioritization techniques.

4.2.1.2 Dependency Mapping Preparation (Step B)

Dependencies were mapped by the same group of professionals as described in the sample above (participants in the same DAIIPS workshop) but with a modified representation over the different roles. In total 10 participants as can be seen in Table 4.

Table 4. Participation Distribution over Roles - Dependency Mapping

Role	No. part.
1: Orderer	1
2: Project Manager	2
3: System Engineer	1
4: Developer	2
5: System Test	1
6: Production	*0*
7: Application Developer	1
8: Management	2
9: Sales/Marketing	*0*
10: Sales Support	*0*
Total	**10**

Some roles, i.e. Production, Sales/Marketing and Sales Support, were not present during the dependency mapping. While other roles more directly linked to system development (active participants and "owners" of the process) were represented.

The main reason for not inviting all roles was that the dependencies between the improvement issues were not obvious to people not working directly with the development, and thus the input from these roles was not premiered. The ten persons chosen for the task of dependency mapping were all active participants within the research and development department, many of which were senior members of the staff with experience from multiple roles over a number of years.

The roles not elicited during the dependency mapping were however present during the prioritization. The rationale behind the two samples was that all roles (presented in Section 4.2.1) could have relevant and important input to what parts of a process that needed to be improved. While knowledge of how the improvement issues were dependent on each other was deemed better explored by the ones that worked with the process every day.

4.2.2. Academia (Validation) Study Design

Sampling (see Section 3.1.1) of the subjects for the prioritization (and later the dependency mapping) was based on convenience sampling [22]. The sample consisted of six PhD students from the Department of Software Engineering & Computer Science at Blekinge Institute of Technology. The students in question were two senior students (had been PhD students for more than 2 years), and 4 junior students (< 2 years).

Criteria were set based on the one used in the industry study, i.e. maximizing the quality of the RE process.

Prioritization technique and **dependency mapping** were done in the same manner as in the industry study described in Section 4.2.1.

4.2.3. Validity Evaluation

In this section we discuss the threats to this investigation. We base this on the discussion of validity and threats to research projects presented in Wohlin et al. [21]. One type of threats mentioned in [21] is not relevant, since the investigation is conducted in an industrial environment. The threat not considered is construct validity, which mainly is concerned with the mapping from the real world to the laboratory. The investigation presented here is however conducted in the real world. The validity threats considered are: conclusion, internal and external validity threats respectively.

4.2.3.1 Conclusion validity

The questionnaire used for the prioritization and dependency mapping was validated through preliminary testing and proofreading by several independent parties, to avoid factors like poor question wording and erroneous formulation.

Each prioritization and dependency mapping was done in one uninterrupted work session. Thus the answers were not influenced by internal discussions about the questions during e.g. coffee breaks.

The sampling techniques used for the industry study can pose a threat to the validity of the investigation. The subjects selected may not be totally representative for the role they should represent at DHR.

The main assurance that this misrepresentation is minimal is the fact that the subjects were selected in cooperation with three senior managers with extensive knowledge and experience with regards to the development processes and the personnel at DHR.

4.2.3.2 Internal Validity

As the prioritization and dependency mapping was done on paper (i.e. there was a record of people's opinions and views) this could have constrained people in their answers. This potential problem was alleviated by the guarantee of anonymity as to all information divulged during the study, and that recorded answers was only to be used by the researchers.

4.2.3.3 External Validity

The external validity is concerned with the ability to generalize the results. As far as the results pertaining to priority is concerned this is not a main threat to the study, since the objective is not generalizing DHR's priorities to other environments (i.e. things important to DHR may be less critical for another company). The important generalization here is whether the applied approach for prioritizing, dependency mapping and packaging improvement issues is possible to apply in other environments. There is nothing in the approach that makes it tailored to the specific setting hence the approach should be useful at other small and medium sized enterprises that would like to choose what improvement issues to undertake in their SPI enterprise.

The academia study was performed to validate that the identified dependencies between the improvement issues were representative for state-of-the art, e.g. that no important and unforeseen dependencies were missed in the industry study. As far as the priority of improvement issues obtained from the academia study is concerned no real validation and/or comparison is relevant. This is because the PhD students are not participants in the DHR organization, thus have no appreciation or insight into the strengths or weaknesses perceived by DHR employees.

4.3. Industry Study Execution and Results

The first part of the DAIIPS workshop (see Figure 7 and Section 3) was to introduce the participants to the nine improvement issues and the official formulation of them, i.e. what each issue meant and what they involved. This was a straightforward procedure since all people had participated in the PA activities earlier. The improvement issues can be viewed in Table 5. The descriptions of the issues (in italic under each issue) are given in abbreviated format.

The next part was to initiate the workshop. A general description covering the form, how answers should be specified, and information about anonymity issues, proceeded the handing out of the forms. Examples were given as to the meaning of the priority scale and questions were answered.

The organizing body of this workshop was present during the entire duration and the participants could ask questions as needed throughout the prioritization.

Table 5. Improvement Issues at DHR

Improvement Issues (in no specific order)
Issue-1: Abstraction level & Contents of requirements *Each requirement should be specified on a predefined level of abstraction with certain characteristics (attributes attached to it), enabling requirements to be comparable and specified to a certain predefined degree of detail.*
Issue-2: Requirements prioritization *This issue suggests a systematic prioritization of all requirements in a standardized way.*
Issue-3: Requirements upkeep during & post project *In order to keep the requirements up to date during and post project the requirements have to be updated as they change.*
Issue-4: Roles and responsibilities - RE process *To avoid misunderstandings as well as avoiding certain tasks not being completed the roles and responsibilities of all project members should be clearly defined before project start.*
Issue-5: System tests performed against requirements *All system tests should be performed against requirements (e.g. using requirements as a base to construct test-cases).*
Issue-6: RE process/methods *This issue is basically the creation and incorporation of a complete and comprehensive Requirements Engineering process at DHR that is well defined and documented.*
Issue-7: Requirements reuse *By reusing requirements everything from the requirement itself to analysis, design, implemented components, test cases, scenarios, and use cases etc. can be reused.*
Issue-8: Requirements traceability *Policies and support for traceability to and from the requirements are to be established.*
Issue-9: Requirements version handling *Policies and support for version handling of each requirement (not only on requirement's document level) should be established.*

The handout included several examples of how priority and dependencies were to be specified. The workshop lasted over two hours time.

4.3.1. Sample and Consistency Ratio

During the compilation of the prioritization results the consistency ratio (CR) was observed for each participant. It varied from a CR of 0.05 (well below the recommended limit) to 0.59 (regarded highly inconsistent). The average CR was ≈ 0.22 (median ≈ 0.16). A summary of the participants CR is given in Table 6.

Table 6. CR for DHR Participants

Subject	CR		Subject	CR
DHR6	0.05		DHR1	0.17
DHR9	0.11		DHR5	0.19
DHR7	0.12		*DHR12*	*0.28*
DHR4	0.12		*DHR13*	*0.30*
DHR14	0.13		*DHR8*	*0.35*
DHR2	0.14		*DHR10*	*0.38*
DHR3	0.14		*DHR11*	*0.59*

The decision was made to include only the results from participants having a CR of 0.20 or less. Going by the recommendation by Saaty of 0.10 would exclude all results except for one participant, i.e. not a practical solution.

This of course had a negative impact on the sample, i.e. the distribution of participants over the roles was altered due to the invalidation of some results (see Table 6, the grey cells).

In Table 7 the impact of the participants with too high CR (>0.20) can be observed. In the left column the roles are listed, the middle column displays the number of people that participated in the prioritization for each role. The last column denotes the total amount that was incorporated in the prioritization results, i.e. those with a CR of less than 0.20 (within the parenthesis the number of people that were excluded from the prioritization can be viewed). The bottom row shows the total, i.e. five people were excluded due to too high CR, leaving nine people.

Some roles were diminished and others vanished altogether, i.e. the Production and Application Developer roles were not to influence the prioritization of the improvement issues at all.

Table 7. Result of Invalidation Impact on Sample

Role	Part. No.	Result (Difference)
1: Orderer	1	1 (0)
2: Project Manager	2	2 (0)
3: System Engineer	2	1 (-1)
4: Developer	2	1 (-1)
5: System Test	1	1 (0)
6: Production	1	0 (-1)
7: Application Developer	1	0 (-1)
8: Management	2	1 (-1)
9: Sales/Marketing	1	1 (0)
10: Sales Support	1	1 (0)
TOTAL	**14**	**9 (-5)**

This "total non-representation" by the two roles was however deemed acceptable, as was the diminished representation of three other roles. The reason for this was that the improvement issue's priority differed relatively little after excluding the persons with high CR (see Section 4.3.2 and Figure 1).

4.3.2. Priority of Improvement Issues (Results - Step A)

The results of the prioritization can be viewed in Table 8 where all nine issues are present. The views of the participants are fairly scattered, although some tendencies of consensus can be observed.

From the *rank* row in Table 7 it is observable that issue *5: System Test* has the highest priority by a marginal of almost 43% ((0.213-0.149)/0.149) in comparison to issue *2: Upkeep* ranked as no. 2.

The issues ranked 2:nd to 4:th only have a moderate difference in priority in comparison (i.e. the difference between issues 2 and 4 is in comparison a moderate 20% ((0.149-0.124)/0.124)).

Looking at Figure 8 the issues are grouped together on a "shelf structure" which illustrates the jumps in priority. The top shelf is occupied with issue 5, then there is a large drop in priority to the next shelf where issues *3: Requirements upkeep during & post project*, *1: Abstraction level & Contents of requirements* and *2: Requirements prioritization* are grouped, and so on. It is noticeable that there are several jumps in priority, and a substantial difference between the issues ranked in the top four and the issues ranked five and lower.

There is a quite large difference in opinion regarding issue *5: System Test* (ranked number one), i.e. a scattering from a priority of only 0.05 to an extreme 0.44 (i.e. more than eight times as high). The scattering is less in issues 2-4 which lie closer in priority.

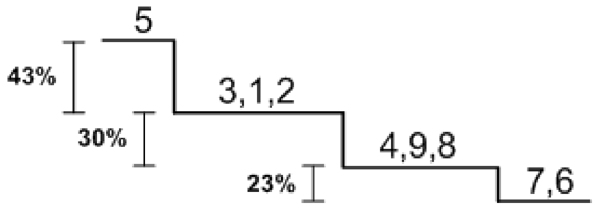
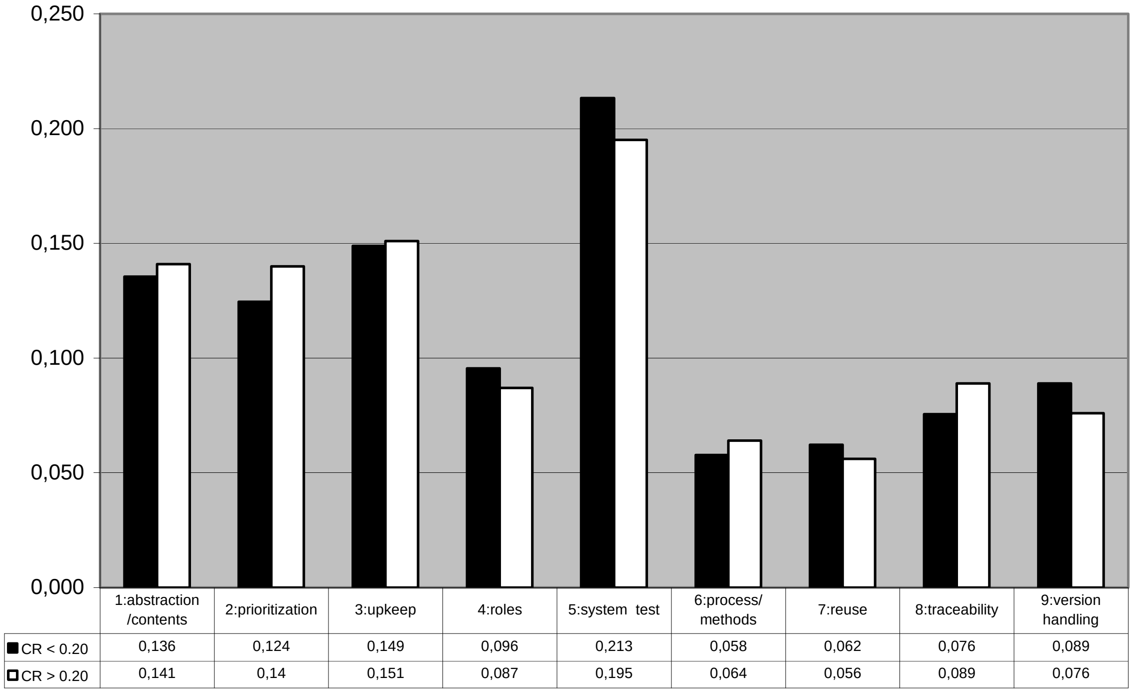


Figure 8. Priority Shelves

Figure 9 also illustrates the priority of the improvement issues. There are two series of data presented, the priorities of the issues by only the participants with CR<0.20 (black bars), and the priorities not excluding the ones with CR>0.20, i.e. all 14 participants included (white bars). It is observable that the priority of the improvement issues is not substantially changed when all 14 participants' results are taken into consideration, at least not for the fist two shelves, i.e. issue 5 is still on step 1, and issues 3, 1, 2 are still on step two. And the changes amongst the other issues are also rather moderate.

Table 8. Priority Results (CR<0.20)

ID	1:abstr/ contents	2:prio	3:upkeep	4:roles	5:sys. test	6:process/ methods	7:reuse	8:traceab	9:version handling	CR
DHR1	0.22	0.07	0.19	0.03	0.26	0.03	0.05	0.07	0.09	0.17
DHR2	0.2	0.14	0.19	0.05	0.22	0.07	0.06	0.06	0.02	0.14
DHR3	0.17	0.07	0.18	0.28	0.1	0.02	0.04	0.05	0.09	0.14
DHR4	0.08	0.24	0.08	0.09	0.25	0.12	0.06	0.03	0.04	0.12
DHR5	0.12	0.14	0.14	0.03	0.17	0.05	0.06	0.1	0.2	0.19
DHR6	0.04	0.16	0.17	0.17	0.05	0.12	0.09	0.13	0.07	0.05
DHR7	0.13	0.15	0.19	0.05	0.18	0.03	0.1	0.08	0.1	0.12
DHR9	0.14	0.09	0.14	0.06	0.25	0.03	0.04	0.11	0.14	0.11
DHR14	0.12	0.06	0.06	0.1	0.44	0.05	0.06	0.05	0.05	0.13
average (CI<0.20)	**0.136**	**0.124**	**0.149**	**0.096**	**0.213**	**0.058**	**0.062**	**0.076**	**0.089**	**0.130**
rank	**3**	**4**	**2**	**5**	**1**	**9**	**8**	**7**	**6**	



	1:abstraction /contents	2:prioritization	3:upkeep	4:roles	5:system test	6:process/ methods	7:reuse	8:traceability	9:version handling
■ CR < 0.20	0,136	0,124	0,149	0,096	0,213	0,058	0,062	0,076	0,089
□ CR > 0.20	0,141	0,14	0,151	0,087	0,195	0,064	0,056	0,089	0,076

Figure 9. Priority Comparison

4.3.3. Dependencies between Improvement Issues (Results - Step B)

As the results from the dependency mapping were compiled the weight of each dependency was recalculated into percent (what percentage of the subjects identified the dependency), and a threshold was set to 20%, i.e. more than 20% of the subjects doing the dependency mapping had to identify the dependency (see Section 0).

The results from the dependency mapping can be seen in Table 9, where the grey cells denote dependencies deemed under the threshold.

The dependencies under the threshold were scrutinized and dismissed, all except one, i.e. dependency *8 on 1* (8: traceability was deemed dependent on 1: abstraction/contents). The reasoning behind this was discussed and consensus reached thus making an exception to the general threshold limit.

A dependency diagram was drawn (see Figure 10). Here the relations, their weight (e.g. 0.6 is the same as 60% in Table 9), and the relations' direction can be observed. Relative priority (the value inside the parenthesis) and rank (top bold numeral) are also visible.

Table 9. Dependencies between Improvement Issues Identified at DHR

Dependency (Issue *i* on issue *j*)	Weight in %
2 on 1	60
3 on 1	*20*
3 on 4	40
3 on 6	*20*
3 on 9	*20*
4 on 6	*20*
5 on 1	60
5 on 2	30
5 on 3	70
5 on 8	*20*
7 on 1	30
7 on 3	60
7 on 6	*20*
7 on 8	40
7 on 9	30
8 on 1	*20*
8 on 3	*10*
9 on 3	*10*

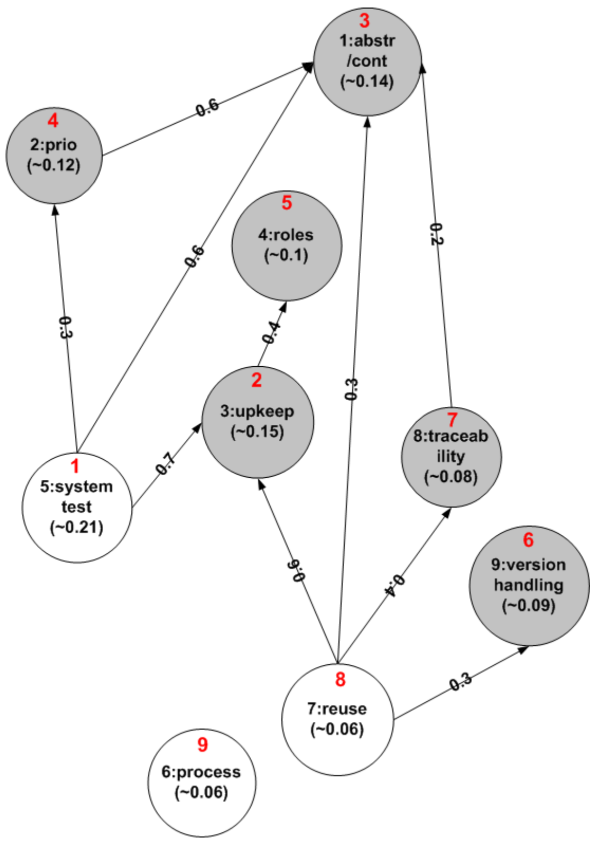


Figure 10. DHR Dependency Diagram

4.3.4. Package Improvement Issues (Results – Step C)

Issue *5: system test* has the highest priority by far, and depends on issues 1, 2 and 3. Issue 3 in turn depends on issue 4. This "unit", i.e. issues 5, 3, 2, 1 and 4 were possible to break out, and put into an SPI package, see Figure 12. This was a seemingly optimal choice with regards to priority and the mapped dependencies. However this packaging (as illustrated in Figure 12) was rejected due to the strain on resources such a large SPI package would demand (especially in terms of time to return on investment). Instead a second proposal for packaging was drawn up taking resources and time into account.

The previously suggested SPI Package *A* (see Figure 12) was divided into two packages, i.e. *2: prioritization* and *5: system test* was broken out to its own package (see Figure 11). This meant that issue 5 (which had the highest priority) was postponed. The reasoning was that SPI Package 1 (see Figure 11) was a prerequisite for SPI Package 2, and that it would probably be implemented in this order anyway, i.e. even if the packaging had been accepted from the first suggestion as seen in Figure 12. The major difference in breaking up package *A* further was for the implementation and evaluation of the implementation to be faster. If package *A* had been kept as the original suggestion more resources and time had to be spent on the SPI before feedback on the implementation of the activities was available. By the further division an evaluation of the work could be done earlier, and a subsequent decision to continue (i.e. with package 2 in Figure 11) or not could be made earlier and at a lesser cost in regards to time and resources.

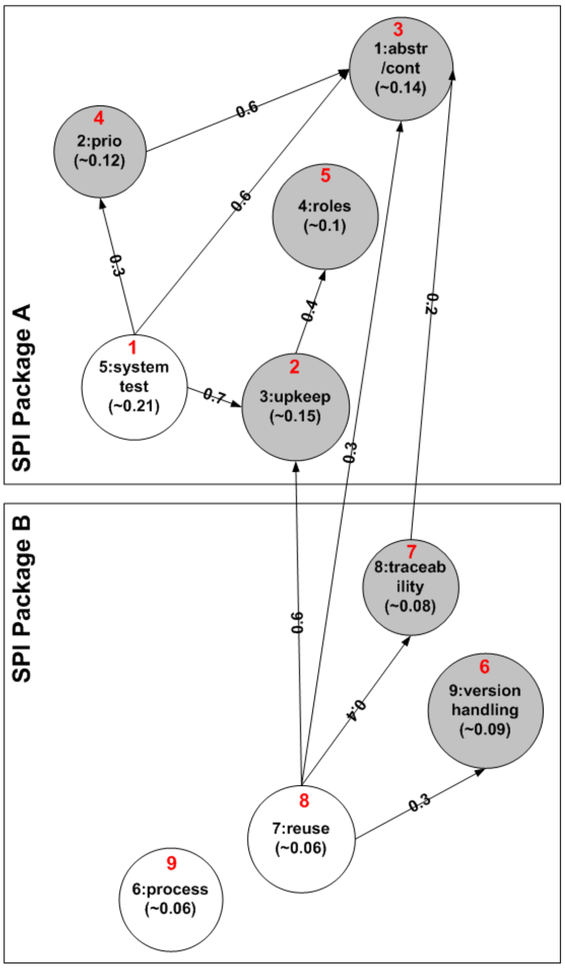


Figure 12. SPI Package Suggestion at DHR

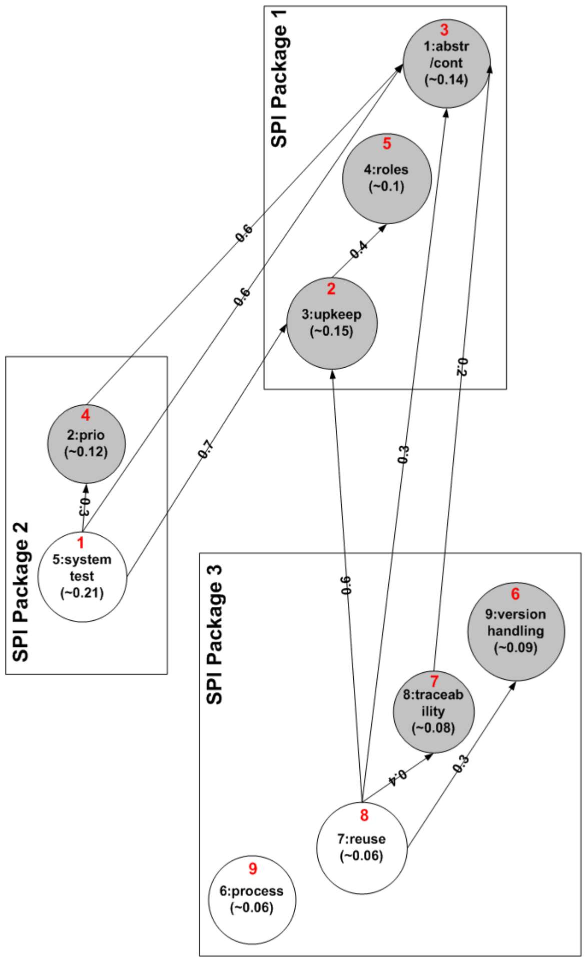


Figure 11. Final SPI Package at DHR

4.4. Academia (Validation) Study Execution and Results

The study in academia preceded much in the same manner as the industry study. The subjects selected were given the same information and the same form to fill out regarding prioritization and dependency mapping of improvement issues.

The workshop was budgeted to two hours, but took only about one hour in total.

4.4.1. Sample and Consistency Ratio

During the compilation of the prioritization results the consistency ratio (CR) was observed for each participant. It varied from a CR of 0.23 (well above the recommended limit set by Saaty and the limit deemed acceptable during the industry study) to 0.62 (regarded highly inconsistent). The average CR was ≈ 0.40 (median ≈ 0.35). A summary of the participants CR can be viewed in Table 10.

Table 10. CR for Academia Participants

Subject	CR
BTH1	0.42
BTH2	0.62
BTH3	0.27
BTH4	0.23
BTH5	0.26
BTH6	0.58

In Section 4.2.3.3 it was stated that there would be no comparison between academia and industry as to the priority of improvement issues as it was not considered relevant. Furthermore it could be said that the CR was very high over all (well over the limit of CR<0.2 used in the industry study), in general disqualifying all participants in the academia study.

However this is as said before of subordinate importance as the academia study was not done in order to confirm/validate the priorities obtained from industry, but rather to compare the dependencies being mapped, in order to get an idea if the dependencies found in the industry study were also found in academia, and vice versa.

4.4.2. Dependencies between Improvement Issues

As the results from the dependency mapping were compiled the weight of each dependency was recalculated into percent (what percentage of the subjects identified the dependency), and a threshold was set to 20%, i.e. more than 20% of the subjects doing the dependency mapping had to identify the dependency (see Section 0).

The results from the dependency mapping can be seen in Table 11.

Table 11. Dependencies between Improvement Issues Identified in Academia

Dependency (Issue *i* on issue *j*)	Weight in %	Dependency (Issue *i* on issue *j*)	Weight in %
2 on 1	83	6 on 4	33
3 on 1	33	7 on 1	67
3 on 4	33	7 on 3	33
3 on 6	50	7 on 6	33
3 on 9	33	7 on 8	33
4 on 6	33	7 on 9	50
5 on 1	83	8 on 1	33
5 on 3	83	8 on 3	50
5 on 8	50	9 on 3	33

It is noticeable that no dependencies identified were specified by less than 33% (i.e. 2 participants in this case).

4.5. Comparison – Industry vs. Academia

4.5.1. Introduction

In this section some comparisons are made between the dependencies identified in the industry study at DHR and the study performed in academia at Blekinge Institute of Technology.

The motivation for the comparison is to validate the dependencies identified in industry (see Section 4.2.3.3). In addition this section provides a chance to observe some differences between the outlook on dependencies between industry and academia.

Table 12 presents a summation of the dependencies presented previously (i.e. in Table 9 and Table 11). The weights for both industry (column two) and academia (column three) are presented in percent. The dependencies are also presented in Figure 13 where dependency weights are presented on the lines (industry | academia).

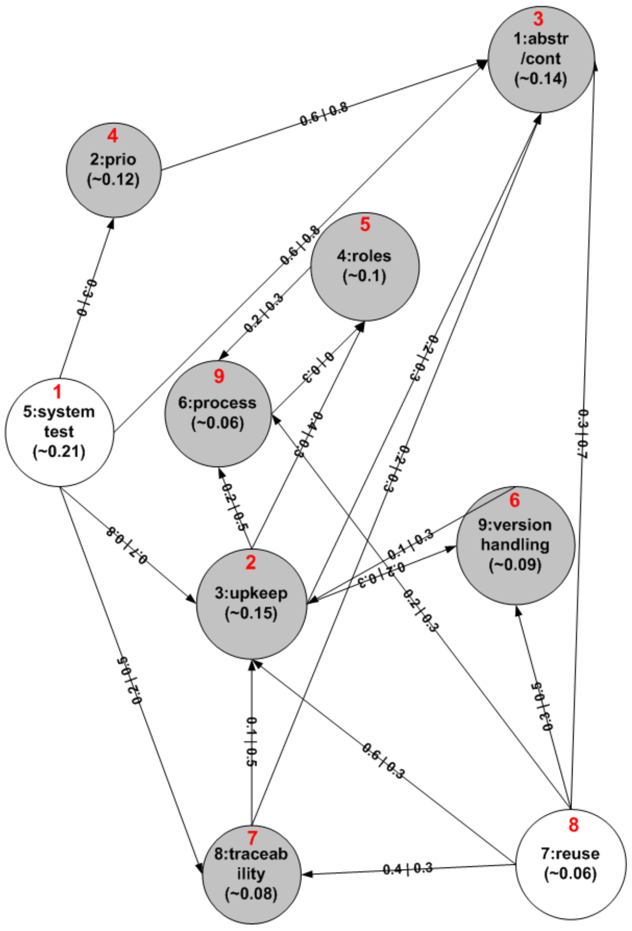


Figure 13. Dependency Diagram Industry and Academia (DHR Priority │ Academia Priority)

Table 12. Dependency Comparison between DHR and Academia

Dependency (Issue *i* on issue *j*)	Weight (%) DHR	Weight (%) Acad.	Note (Group)
2 on 1	60	83	1
3 on 1	20	33	4
3 on 4	40	33	2
3 on 6	20	50	3
3 on 9	20	33	4
4 on 6	20	33	4
5 on 1	60	83	1
5 on 2	30	*0*	6
5 on 3	70	83	1
5 on 8	20	50	3
6 on 4	*0*	33	5
7 on 1	30	67	2
7 on 3	60	33	2
7 on 6	20	33	4
7 on 8	40	33	2
7 on 9	30	50	2
8 on 1	20	33	2
8 on 3	10	50	3
9 on 3	10	33	5

4.5.2. Comparison Analysis

Below some analysis and augmentation is provided on the dependencies listed in Table 12. The note column holds numbers that have corresponding numbers in the text below, i.e. some analysis is offered for each number. In some instances the dependencies are grouped together with regards to common properties or tendencies.

Note 1: There is strong support for the dependencies in this group, both in industry and in academia. All of the dependencies in this category were taken into consideration during the packaging activity performed (see Section 4.3.3). The dependencies here are not analyzed or commented upon any further.

Note 2: This group also holds dependencies that all were taken into consideration during the dependency mapping, i.e. all had a weight above the threshold in both industry and in academia. However in comparison to group 1 the weights are lower, i.e. most weights are ≤ 50%. In addition to this there are some discrepancies between industry and academia. This is especially clear in the case of dependency *7 on 1* (having a much stronger weight in academia than in industry), and *7 on 3* (showing the opposite, i.e. stronger weight in industry). In academia issue *7: Requirements reuse* is considered to be linked primarily to how the requirements are specified (issue 1) while the dependency on issue *3: Requirements upkeep during & post project* is considered of less weight. In industry the tables are turned, i.e. issue 3 is premiered. One explanation for this could be that the participants from industry see out-of-date documents, e.g. requirement specifications, as an undesirable but relatively common occurrence in projects. While people based in academia in this case may have premiered other aspects due to that they are not faced with this particular problem in their daily work.

Note 3: In this group there is a clear discrepancy between industry and academia, i.e. dependencies identified as rather strong (50%) in academia are considered weak in industry (≤ 20%). This group is has the strongest candidates for adding to the dependencies identified in industry, i.e. catching dependencies missed in the industry mapping. The three cases in this group will be analyzed one by one below.

3 on 6: In the case of dependency *3 on 6* (*6: RE process/methods*) the motivation behind this in academia was generally that a documented process helped in the upkeep of requirements. In industry however the general perception was that the presence of a documented process did not ensure anything, and that focus should be put on establishing practices for issues, and that a complete and comprehensive documented process was not a prerequisite for any of the issues identified.

Looking at issue *6: RE process/methods* there are a number of instances where dependencies are identified both to and from this issue (in groups 4 and 5). In industry the identified dependencies were under the threshold (see Section 4.3.3) in all cases and thus had no impact during the dependency mapping. In academia the dependencies were over the threshold. One possible explanation for industry not premiering this issue (not in the case of either priority or during the dependency mapping) could be that there is some disillusionment towards official documented processes, i.e. in many cases representing a largely unused set of steps, rules, practices etc. The mindset was that documenting something and making it official did not necessarily promote it or make it used (or even useful) by the participants in the organization.

5 on 8: In the case of dependency *5 on 8* the general reasoning in academia was that there had to be traceability policies in place in order for system tests to be performed against requirements. This would enable e.g. faster tracking of faults from test cases (based on requirements) and the modules/classes/code.

A dependency between test and traceability was identified in industry also but from a different perspective, i.e. the reason given was that test could be performed on requirements only if it would be possible to trace which of the requirements that were implemented. This rationale (and thus the dependency) was however not seen as critical due to that all requirements allocated to a certain project should be implemented. If the requirements in question were not to be implemented for any reason they would be removed from the project.

In the case of this dependency there is a good chance that the academia view could benefit the industry case.

8 on 3: The reasoning behind this dependency in academia was that requirements not updated were prone to make traceability difficult, if not impossible. However this dependency was not considered critical in industry.

In the case of this dependency there is a good chance that the academia view could benefit the industry case.

Note 4: In this group the dependencies were identified in both cases, but the weight in industry was just below (or actually on) the threshold, i.e. 20%. In the case of academia all the dependencies had a weight of 33%, just above the threshold, i.e. identified by two persons (2 out of 6 = 33%). There are some implications that could be attributed to this, i.e. that one person less in the case of academia would make this category a non-issue in this analysis.

Given that the dependencies here are rather weak looking at the combination of both cases the dependencies in this group are not considered as strong candidates for adding to the dependencies identified in industry. This is further supported by the fact that two out of the four dependencies in this groups are on issue *6: RE process/methods* (the rationale behind dependencies and this issue was discussed above under note 3).

The two other dependencies under this group are discussed below.

3 on 1: The reasoning behind this dependency in academia was that the abstraction level and contents of a requirement made it easy or hard to keep a requirement updated. This dependency was also identified in industry but the reasoning behind the dependency was rather that someone had to keep the requirements updated (thus the dependency on issue 4), i.e. identifying that *how* the requirement was specified could impact on keeping it updated, was not premiered.

3 on 9: This dependency was identified in both studies, and the rationale behind it was that version handling helped in the upkeep of requirements. This was however not considered critical in industry because version handling of the requirements document was considered adequate for the time being and that issue 9 would be implemented later, possibly in combination with CASE tool support.

Note 5: This group shows a large discrepancy between industry (dependency weights well below the threshold) and academia (dependency weights just below the threshold). The weights are fairly weak even in the academia case, thus these dependencies are not considered as strong candidates for adding to the dependencies identified in industry. This is further supported by the fact that one out of the two dependencies in this group is from issue *6: RE process/methods* (the rationale behind dependencies and this issue was discussed above under note 3).

In the case of dependency *9 on 3* the reasoning in academia was that upkeep of requirements was the basis for creating versions, i.e. the point of creating versions.

In industry the dependency was seen as versions had to be created manually (i.e. up-kept). This reasoning was however not seen as critical since the idea was for this to be handled by some sort of tool later on (e.g. a CASE tool as mentioned in relation to dependency *3 on 9*).

Note 6: The dependency *5: System tests performed against requirements* on *2: Requirements prioritization* was identified in industry but not in academia. The motivation behind this dependency in industry was that in order to know what requirements to premiere in the testing it was important to ascertain which were prioritized, i.e. implying that there were not always resources to pay equal attention to all parts and test all parts as extensively as would be preferable.

4.5.3. Comparison Summary and Discussion

It should be restated that the comparison between dependency mappings in industry and academia was performed to validate the dependencies found in industry, i.e. strengthening the external validity of this study by alleviating the risk of crucial dependencies being missed.

Two prime candidates for adding to the dependencies found in industry were identified through the academia study, namely *5 on 8* and *8 on 3* (see note 3).

The impact of these dependency additions to the industry case in this instance has to be taken under advisement.

In the case of dependency *8 on 3* the effects on the SPI package is minor, almost non-existent. Looking at Figure 11, which displays the final SPI packaging at DHR, no action has to be taken. I.e. the new dependency does not force any reallocation of improvement issues between the packages 1 through 3.

In the case of dependency *5 on 8* the impact is greater though. In order for the dependency to be satisfied issue 8 has to be moved to either package 2 (and supersede implementation of issue 5), or be moved to package 1. In either case there is a reallocation of an improvement issue and a subsequent increase in the size of the affected package.

Looking at the other dependency comparisons the discrepancies between the studies were of less impact. Most dependencies identified in one study were also seen in the other, barring a few exceptions.

Some of the most prominent were dependencies to and from issue *6: RE process/methods*. The industry view was more pragmatic than the one in academia, i.e. recognizing that an official and documented process is seldom a guarantee for things actually being done at all, not to mention done in a certain way which is set down on paper.

This difference in outlook between industry and academia is also seen in the case of testing being dependent on having priority on the requirements, i.e. *5 on 2* (note 6). The assumption in academia can be that all implemented components are tested. This is true in the industry case as well (as probably all parts are tested), but limited resources and tight deadlines may result in some prioritization as to the degree of testing.

5. Discussion and Conclusions

In the introduction to this paper several reasons were given motivating the construction of the DAIIPS scheme. The primary motivation was to give SMEs a decision support scheme that considered several aspects identified as critical for the success of SPI endeavors. The need for this was initially identified in industry, i.e. in the case of the SPI activity performed at Danaher Motion Särö AB.

In the first part (Section 3) we present DAIIPS, both how improvement issues are prioritized, and how dependencies between issues are identified and visualized. The objective is that this information act as input to an informed decision regarding what actions to take in terms of process improvement.

The developed method is subsequently applied at a company (Section 4), and it is shown how it was used in an industry setting to allocate improvement issues into SPI packages taking priority, dependencies and (to a certain extent) cost into consideration.

Modularity was also premiered in the development of DAIIPS. The scheme is independent, speaking to that any method (e.g. CMMI, SPICE etc) can be used for the proceeding SPA activity, as long as the assessment data be available. The same is true for the implementation of the issues after the DAIIPS packaging, enabling organizations to lift in DAIIPS as a decision support scheme regardless of environment. This is of course dependent on factors such as that there is input from the SPA in some comparable form, i.e. considering abstraction level.

Looking at the industry case presented in this paper the focus was not on general SPI but rather on improving a sub-process, namely requirements engineering. In the DHR case this was the area that needed to be improved, using DAIIPS enabled the creation of decision support material for the continuation of the improvement work after the assessment stage.

SPI efforts are often an expensive undertaking, thus effectively raising the threshold for companies and especially SMEs. The general idea behind DAIIPS was to offer a way in which the threshold could be lowered, by offering a structured way to increase the control of aspects such as *time* to return on investment and *cost* of SPI.

Furthermore, other points argued as critical for the success of SPI undertakings (see Section 2.1) were also taken into consideration during the development and use of DAIIPS:

- *Commitment* by management and middle management is easier to secure if management feels in control of the issues of *cost* and *time*.
- *Commitment* by staff, e.g. engineers, (often seen as the most critical issue in regards to SPI success) can be positively influenced by the fact that the prioritization and dependency mapping is largely done by representatives from their "ranks".
- *Focus* on a delimited number of improvement issues at a time (i.e. a SPI package) offers clear and well-defined goals that are obtainable.
- *Involvement* (in the SPI work by staff) is easier to secure if the staff has a say in what is to be done from the start.

Enabling the professionals in the SPI targeted organization to "take matters into their own hands", prioritizing, mapping dependencies and packaging issues according to their needs, should be premiered. It is important to remember that no method, framework or scheme (or even DAIIPS for that matter) is useful if the professionals, whose organization is targeted for SPI, are not committed.

In summary, the paper presents a method for prioritization and identification of dependencies between software process improvement proposals. The method is applied successfully in an industrial case study involving an organization being classified as a small and medium sized company.

6. Further Work

Refinement, Expansion and Replication are three key words that are central for the future of the DAIIPS scheme.

DAIIPS as a scheme needs to be refined through the tweaking of the steps of which it is comprised. Lessons learned from the studies thus far need to be evaluated, weaknesses need to be identified and dealt with by further simplification of the scheme were possible.

DAIIPS could be augmented by the incorporation of cost as an official and modeled part or the scheme, thus offering further dimensions to the decision support offered.

Replication of the study presented above is almost a prerequisite in order for the DAIIPS scheme to be tested, and in doing so producing results that allows DAIIPS to evolve. This includes testing the use of alternative prioritization techniques.

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