Challenges of Chinese Industrial Solution Projects

Ming Yu, Ying Liu, and Adrian Koehlein

***Abstract*—Industrial Solution Business, shortened ISB, concentrates on the development and engineering of large-scale and complex systems. As the economy develops, ISB has taken a more and more important position in the industrial projects, especially in China where a great amount of projects are being under construction. In order to improve the engineering quality, a series of investigations have been carried out to find out the major "pain points" project managers in that area are faced with. The pain points or challenges were collected and analyzed through interviews and research, promoted through a series of questionnaires, and then shaped into a structural model. The purpose of this research is to locate the main problems and to improve industrial solution projects. This publication depicts the current work in progress especially focusing on the identified challenges in industrial solution business.**

***Index Terms*—Challenge, Industrial Solution Business, Systems Engineering, Process Management**

I. Introduction

Nowadays, it's much more difficult to manage all the problems that come out here and there due to the fierce competition within the market, especially in our focused area — Industrial Solution Business. Thus we're very interested to find out what are the exact challenges in order to get solutions for them.

First let's take a look at what ISB actually is. An industrial solution is a kind of engineering project addressing the individual customer requirements. In general, it is a big and complex engineering project, varying in product engineering which usually focuses on the requirements collection of customers [2]. It is more like a real engineering project as it has only one chance to realize a target system.

While many internationally accepted standards in other areas of project management have been developed, there is still no widely acknowledged standard in the domain of ISB. The situation is even more obscure in China where a great amount of projects are booming. In order to get a deeper understanding of this business and provide useful references to industry players, Tsinghua University Beijing and Siemens Corporate Technology have made a joint effort to carry out the research on how to improve ISB, especially for the Chinese market.

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This research starts from the definition of ISB and reviews of existing related standards, such as Project Management Institute (PMI), Capability Maturity Model® Integration (CMMI), and ISO 9000 etc. While understanding these references, a series of investigations were organized, aiming to get feedback from the Chinese industry which in turn was used to guide the academic research. The principle of the later research is that the major concerns and difficulties faced by industry should be addressed and met. In the following sections, the approach of the investigation will be presented in detail. The target challenge list of ISB will be shown at the end.

II. ISB and Complexity

Initially the research begins with the understanding of ISB. Industrial solution is a kind of engineering project sticking to customer's requirements, and sequentially, Industrial Solutions Business is then defined as a business which concentrates on the development of industrial solutions [2]. ISB projects generally have the following features: large-scale, complex, inter-disciplinary and customer-need-specific. While the other three features are easy to understand, it is comparatively subtle to define "complexity".

There are different views toward complexity. We adopt the one as: A complex system is a system formed out of many components whose behavior is emergent. That is to say that the behavior of a complex system cannot be simply inferred from the behavior of its components [1].

The complexity could be categorized according to the system's features. They could be divided into two dimensions: structural/dynamic and independent/interacting as showed in Figure 1.

Apparently, the No.4 "Interacting dynamic complexity" is the most complex one with a dynamic system and interacting relationship among its subsystems. This most complex part within the SDI matrix will be reference for later industrial investigation. In the next part, the procedure of the identification of challenges is showed from theory to practice

	Independent	Interacting
Structural	1. Independent structural complexity	2. Interacting structural complexity
Dynamic	3. Independent dynamic complexity	4. Interacting dynamic complexity

Fig. 1 Structural dynamic interaction (SDI) matrix [1]

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III. IDENTIFICATION OF CHALLENGES

Based on above understanding of ISB, an original challenge list was worked out according to existing standards in related fields, such as project management, process management, etc. With this initial one, further modifications were made according to the feedback from industrial investigation. At last, this challenge list was finalized with explicit explanations why these challenges became barriers to ISB.

A. Methodology of the research

The whole research process is shown in the following Figure 2. Before the investigation, a conceptual structure was created in order to keep the inner consistency and the extendibility of the study. The challenge structure was created based on an initial challenge list which comes from literature review and workshops, and also based on the results from face to face interviews. The challenges structure will also be the foundation of the quantitative questionnaire. Consequently from the data analysis of the questionnaires we'll gather feedback from industry through a workshop, and then come to our conclusion of the research.

It has to be noticed that, interviews are very valuable, thus the face to face interview can be done with quantitative investigation in the same interview to be more efficient.

1) Challenge domains and corresponding standards

Project management standards are composed by both academic scholars and enterprise professionals, with a lot of industry practices as basis. Therefore it is reasonable to learn from these standards and select certain domains as the basis of our challenge list.

Table 1 shows the challenge domains that we selected from project management standards such as PMI, CMMI and System Engineering Discipline.

The challenge domains are the general categories of the challenges; more specific challenges can be proposed during the interview process. Moreover, our focus is the solution design phase of the projects, so not all listed challenges are necessarily the major concerns of this particular phase. Some of the challenges are to be deleted after the first round of face to face interviews and will not enter the quantitative questionnaire.

Table 1 challenge domains and corresponding standards

Reference Source	Challenge domain
PMI[3]	Integration Management
	Scope Management
	Time Management
	Procurement Management
	Cost Management
	Risk Management
	Quality Management
	Communication Management
	Human Resource Management
CMMI[4]	Requirement Management
	Configuration Management
System Engineering Discipline[6]	Complexity Management
	Knowledge Management
	Technology Management

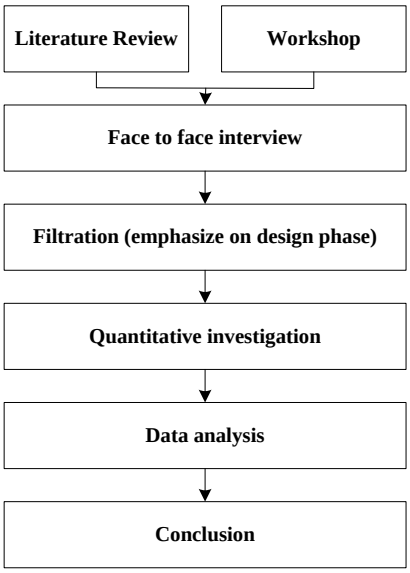

Fig. 2 Methodology of the research

2) Definition of major challenges selected from existed standards.

The definitions of the selected challenge domains, according to the project management standards, are shown in the following: [3][4][6]

Integration Management—it includes the processes required to ensure that the various elements of the projects are properly coordinated.

Scope Management—it includes the processes required to ensure that the project includes all the required work, and only this one in order to complete the project successfully.

Time Management—it includes the processes required to ensure timely completion of the project.

Cost Management—it includes the processes required to ensure that the project is completed within the approved budget.

Risk Management—it's the identification of potential problems and implementation of risk mitigation plans.

Quality Management—it includes the processes required to ensure that the project will satisfy the needs for which it was undertaken.

Requirement Management—it includes the identification and trace of features and their changes of customer requirements.

Communications Management—it is the systematic planning, implementing, monitoring, and revision of all channels of communication within an organization, and furthermore between organizations; it also includes the organization and dissemination of new communication directives related to an organization, network, or communications technology.

Configuration Management—it includes the establishment and maintenance of the integrity of engineering results.

Complexity Management—it comes out while the system becomes very complex or large in scale, and there may be problems like system integration or the tracking of historical changes, as well as the evaluation of potential solutions.

Knowledge Management—it comprises a range of practices used in an organization to identify, create, represent, distribute and enable adoption of insights and experiences.

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Procurement Management—it includes the processes to purchase or acquire external products, services, or results enabling the project team to perform.

Technology Management—it comprises the integrated planning, design, optimization, operation and control of technological aspects as well as management of the technology usage.

Human Resource Management–it includes the processes to organize and manage the project team. The project team comprises people who have assigned roles and responsibilities in order to complete the project successfully.

B. *Industrial feedback*

After we got our initial challenges list, we performed a sequence of interviews both face to face and quantitative investigation. The industry's feedback helped us immensely in reflecting the current situation of the industry. We analyzed the feedback and revised the research results, and this circle went on until we get minor changes to the challenges list which is characterized as the target challenge list.

1) Background

As you can see from Table 2, the domains of the interviewee vary from automotive engineering to civil engineering to others, and the project content varies also from capacity enlargement to R&D of new products etc. Although they are so different, the projects have the same characteristics as they are all included in the ISB.

We didn't just visit them once, but repeatedly asked their opinions on our research any time we had progress. In the next sub-chapters, the approach of how we get feedbacks from the industry is introduced.

2) Approach

For the companies stated above, we first had face to face interviews and quantitative investigations. After that, a few workshops were organized to share knowledge of the work in progress research with the industry. This enhanced a strengthened communication as well.

a) Face to face interviews

The face to face interviews were carried out mainly with project managers in their company, so it is also an on-site interview. It is divided into four phases: introduction, open questions, structured questions and questionnaires.

Introduction—at the beginning of the interview, the project background is introduced but without too much stress. This is to avoid potential influence over the interlocutor's thinking. As we have noticed in our research process, the interlocutors tend to make different responses depending on whether or not they are told the emphasis of this research (focusing on system engineering).

Open questions—the interlocutor is asked to propose openly all major challenges he/she has encountered.

Table 2 Background of the interviews

No.	Domain	Location	Content
1	Automotive Engineering	Beijing	Capacity enlargement
2	Aviation Engineering	Luoyang	R&D of new products
3	Railway Engineering	Tianjin	Railway construction
4	Civil Engineering	Yinchuan	Technical renovation
5	Software Engineering	Beijing	Information system
6	Nuclear Application	Beijing	Product R&D
7	Automotive Engineering	Jinan	Technical renovation
8	Medical Equipment	Beijing	Healthcare equipment design
9	Civil Engineering	Tianjin	Municipal design

Structured questions—the interlocutor will be asked four questions according to the four predefined categories: what are the important/frequently happening/workload consuming/hard to solve problems?

Questionnaire—the interlocutor only needs to pick out the five most important challenges from the challenge list hence this questionnaire is qualitative.

b) Quantitative Investigation

We did not only take the quantitative investigation in the face to face interview, we also send questionnaires via emails to get more statistical data. Some parts of the questionnaire are shown in Figure 3.

The questionnaire is based on the latest challenge list with a brief explanation. For each challenge there are five choices for the experts' opinion on the challenge: (1) not exist; (2) not important or can be ignored; (3) partly important; (4) important; (5) very important. Moreover, at the end of the questionnaire, we left blanks for the experts if they think there are more challenges except for those listed above.

At the very beginning, we state the background of the research, and ask the participants to focus on the design stage while choosing the importance degree for each challenge. Also there are notes about the structure of the challenge at the beginning of the questionnaire

c) Workshop

Every year, there will be hold a workshop to review research progress and results. The workshop functions as a window to the outside of the project.

Directed by the workshop 2007, the work of year 2008 has been mainly focused on the challenges faced by industry; thereby the theme of the workshop 2008 was to get feedback from industry on the work we've done so far and on the direction of the study. The main results of the workshop include statistics of challenge interviews, opinions from

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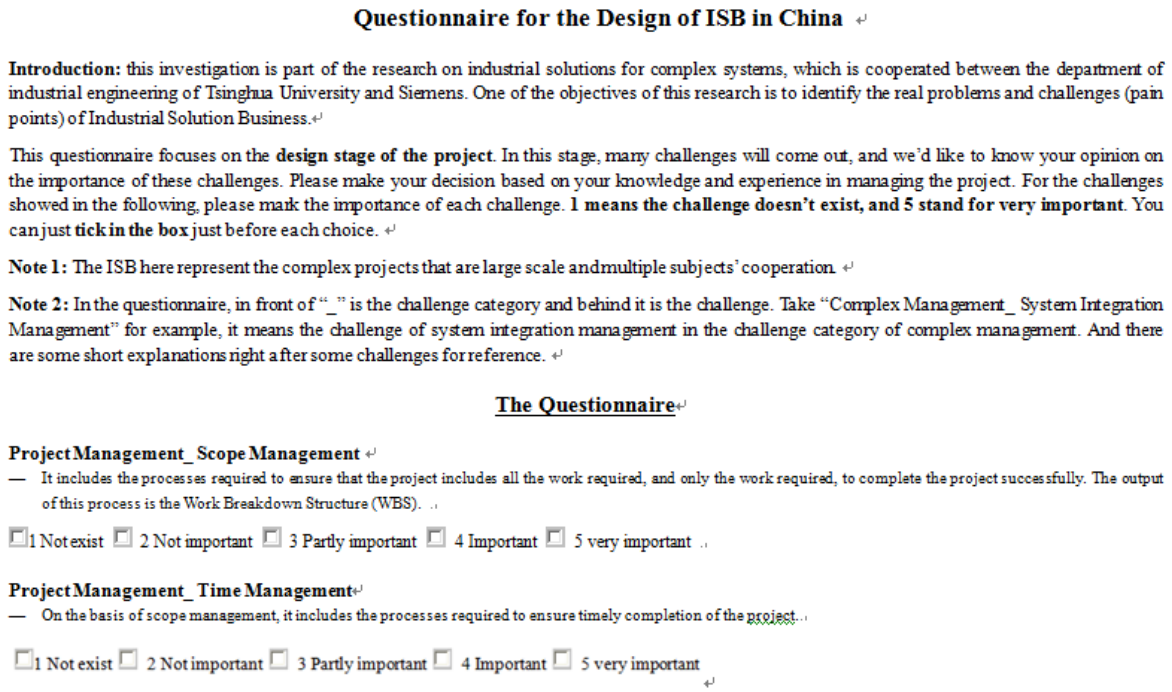

Questionnaire for the Design of ISB in China

Introduction: this investigation is part of the research on industrial solutions for complex systems, which is cooperated between the department of industrial engineering of Tsinghua University and Siemens. One of the objectives of this research is to identify the real problems and challenges (pain points) of Industrial Solution Business.

This questionnaire focuses on the **design stage of the project**. In this stage, many challenges will come out, and we'd like to know your opinion on the importance of these challenges. Please make your decision based on your knowledge and experience in managing the project. For the challenges showed in the following, please mark the importance of each challenge. **1 means the challenge doesn't exist, and 5 stand for very important**. You can just **tick in the box** just before each choice.

Note 1: The ISB here represent the complex projects that are large scale and multiple subjects' cooperation.

Note 2: In the questionnaire, in front of "_" is the challenge category and behind it is the challenge. Take "Complex Management_ System Integration Management" for example, it means the challenge of system integration management in the challenge category of complex management. And there are some short explanations right after some challenges for reference.

The Questionnaire

Project Management_ Scope Management

— It includes the processes required to ensure that the project includes all the work required, and only the work required, to complete the project successfully. The output of this process is the Work Breakdown Structure (WBS).

☐1 Not exist ☐ 2 Not important ☐ 3 Partly important ☐ 4 Important ☐ 5 very important

Project Management_ Time Management

— On the basis of scope management, it includes the processes required to ensure timely completion of the project.

☐1 Not exist ☐ 2 Not important ☐ 3 Partly important ☐ 4 Important ☐ 5 very important

Fig. 3 Part of the questionnaire

community members, feedbacks from meeting participants and the outlook on future study.

1) Feedback from Industry

Summarizing the feedback from the industry by face to face interviews, quantitative investigations and workshops, we constructed the first and second level of the challenge list as shown in Table 3 and Table 4. In the following WS is the abbreviation of workshop, and INV is the abbreviation of interview.

Along with the results from the literature review, we could conduct the target challenge list as explained in the next chapter

IV. Challenges in China's ISB

Based on the research from theory and practice, the challenge list is established. This chapter will present the target challenge list and the definition and explanation for each challenge.

A. Challenge list and definitions

After combining the challenges from internationally accepted standards and feedback from the industry in China, the target challenge list came out as showed in Table 5. The target challenge list has 8 major challenges and 22 sub-challenges. This classification took shape from the interviews and developed along the research, making the challenge list more structured and clearer, furthermore, the solutions to these challenges can be simplified by sticking each challenge to the challenge category.

These challenges come from PMI, our interviews and the workshops. For the second turn of interviews, most of these challenges are cited very important or important. Thanks to its large extent this challenge list can explain most of the problems arising in Chinese industrial solution business. Their definition and explanation are shown in the next sub-chapter.

B. Definitions of the challenges

Along with our understandings and results of the literature review, we compiled a definition for each challenge in the final challenge list above.

Table 3 First level of challenge list based on feedbacks from industry

No	Challenge	Source
1	**Planning Management**	Tsinghua
2	**Quality Management**	WS07, PMI
3	**Knowledge & Technology Management**	INV1
4	**Complexity Management**	WS07
5	**Environment Management**	Tsinghua

Table 4 Second level of challenge list based on industry feedback

No	Challenge	Source
2.1	**Requirement and claim management**	WS07
2.2	**Management and control the staged results**	INV1
2.3	**Monitoring mechanism**	INV1
3.1	**Knowledge management**	INV1
3.2	**Technology management**	INV1
4.1	**Configuration management**	WS07
4.2	**System integration**	INV1
4.3	**Choice making among different solutions**	INV1
4.4	**Ensuring of feasibility of the solution**	INV1
4.5	**Realizability of the solution**	INV2
5.1	**Customer Relationship Management**	INV0
5.3	**Policy and Standard Management**	Tsinghua

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Table 5 Target challenge list

Planning management	Scope management
	Time management
	Integration management
Quality management	Requirement and claim management
	Management and control of the staged results
Knowledge management	Methodology and tools management
	Information, data and parameter management
Technology management	Use of the new technology and fulfill customers' requirements
	Problems tackling in key technology
	Prospective research on specialized topic
Complexity management	Configuration management
	System integration
	Choice making among different solutions
	Ensuring of feasibility of the solution
Environment management	Customer Relationship Management
	Procurement Management
	Policy and Standard Management
Risk management	Risk to the project
	Risk to the user
Others	Communication management
	Human resource management
	Cost management

1) Planning Management

Insure that the right resources are allocated to the right activities at the right time.

It includes the integration of different elements, the definition of activities to be done and the management of milestones.

a) Scope Management

It includes the processes required to ensure that the project includes all the required work, and only this one in order all the required work, and only this one, to complete the project successfully. It is primarily concerned with defining and controlling what is in-/excluded in the project.

b) Time Management

It includes the processes required to ensure timely completion of the project, such as activity definition, activity sequencing, activity duration estimating, schedule development and control.

c) Integration management

It's about making integration and optimization on the basis of scope management and time management.

2) Quality Management

Insure the quality of the engineering results.

It includes the processes required to ensure that the project will satisfy the needs for which it was undertaken. It includes all activities of the overall management to determine the quality policy, objectives and responsibilities as well as to implement them by means of such as quality planning, assurance, control and improvement within the quality system.

a) Requirement and Claim Management

It's the identification and trace of features and their changes.

b) Management and control the staged results

The staged result should be confirmed by the customers whether they are consistent with the overall goal.

3) Knowledge Management

Knowledge Management comprises a range of practices used in an organization to identify, create, represent, distribute and enable adoption of insights and experiences. Examples of such knowledge are either embodied in individuals or embedded in organizational processes or practice. Typically Knowledge Management efforts to focus on organizational objectives such as improved performance, competitive advantage, innovation, the sharing of lessons learned, and continuous improvement of the organization.

a) Methodology & Tools Management

The methodology and tools in the process of determines the solution. "Solution" here means the system architecture design before the detailed design.

b) Information, Data & Parameters Management

The management of project related data and parameters.

4) Technology Management

It means the integrated planning, design, optimization, operation and control of technological aspects as well as the management of the technology usage.

a) Maturity of technology

The technology needed for the project is still not developed enough for industrial application, leading to difficulties in solution selection and technical problems afterwards.

b) Key technology tackling

It refers to the research on key technology after the solution is determined. For various reasons such as the inevitableness of the usage or need for technology innovation, some immature technologies have to be used in the solution. In the design process, these technical issues have to be tackled inevitably.

c) Prospective research on specialized topics

For those technologies not yet mastered but having a great chance of being used in future projects (according to the tendency forecast by the enterprise), they need to be identified and researched ahead of time.

5) Complexity management

It is the coordination and decision making of multi-objective, multidisciplinary, large-scale system engineering. "Complexity" refers to such a system characteristic: the overall behavior of the system could not be deduced from the behavior of its sub-systems. When the system is influenced by multiple interacting factors—such as systems being composed of interacting parts or the cooperation between different departments—the complexity occurs.

a) Configuration Management

Establish and maintain the integrity of engineering results; more technique related, for example, setting parameters in software engineering, keeping technical documents consistence, etc.

b) System Integration

Problems caused during integration of the sub-systems. It is more technique related. For example, the various sub-systems bought from different suppliers are difficult to be integrated due to different technical platforms or interfaces.

c) Decision making among different solutions

When choosing from different solution proposals, the

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trade-off between diverse objectives, stakeholders and members of different disciplines makes it difficult to reach a census. The converging of opinions and reaching a final result takes a lot of time and energy.

d) Ensuring of feasibility of the solution

Before the system is put into operation, the effectiveness of the solution is based on forecasting. Ensuring the feasibility is very important; otherwise huge cost would be wasted. The feasibility of the solution is decided by many factors, causing the complexity of prognosis.

6) Environment management

Sometimes challenges arise from outside of the organization and are impossible to be fully controlled or forecasted. They are related to the environment of the organization. It includes the management of relations with customers, suppliers, governments and communities, etc.

a) Procurement Management

It's the determination of outsourced parts and the relationship management with suppliers. It involves two aspects: the first is the determination of which parts are to be outsourced, the parameters of these parts and selection of suppliers; the second is the management of suppliers after the order is sent, to ensure the parts are delivered in time and meet the quality standards.

b) Policy and Standard Management

It's the management of information on government policies and industry standards. It involves the correct understanding and application of the latest related standards, ensuring the design meets the national policy and standard. For the leading players in the industry (with highest competence and market share), they could exert their influence to initiate some reforms of policies and standards.

7) Risk Management

Identification of potential problems and implementation of risk mitigation plans.

It is the systematic process of identifying, analyzing, and responding to project risks. Normally, risk management includes two aspects: maximizing the probability/consequences of positive events and minimizing the probability/consequences of adverse events to project objectives. In our research, we focus only on the second facet.

Usually, risk management includes phases of risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning and monitoring during the implementation.

There are two kinds of risk management, one focuses on the risk to project, the other one on risk from the project results to user.

a) Risk to project

Risk to project means the thread which is harmful to the success of project. The purpose of the management to this kind of risk is to ensure the success of the project itself. For example, if the project team fails to tackle a key technology challenge, the whole project may fail to reach a result. This is the normal risk management in project management. In other words, it's the "risk of failure" (compared to "risk of safety").

b) Risk to User

Risk to user means the danger which is harmful to the users of project's deliveries. The purpose of this challenge is to ensure the safety of users and the environment. The health care equipment development concerns crucially on this. For example, some medical equipment is operated by buttons. If the operator presses the wrong button during the operation, the result may be serious and irreversible, causing huge damage to the patient. It's the "risk of safety".

8) Others

As a matter of course the above categories cannot include all aspects, therefore some sub-challenges having less relation to ISB, however too much importance to be left out, are grouped into this class, called "others".

a) Customer relationship management

This aspect is related to the maintenance and improvement of customer relationship, especially during off-project times when there is no contract constraint between the customer and solution provider. It involves the pre-project communication with customers and post-project maintenance of customer relationships.

b) Cost management

It involves the estimation of project costs and ensuring the project is completed within the budget. It includes the resource planning, cost estimation, budgeting and control.

c) Human resource management

It involves the process of organization and management of project teams. Human resource management focuses more on the dispatch of human resources, the establishment and implementation of performance appraisals and incentive mechanisms.

d) Communication management

It is the systematic planning, implementing, monitoring, and revision of all the channels of communication within an organization, and between organizations.

By now, we have finished our research about the challenges of ISB in China; we'll briefly summarize our research in the conclusion chapter and slightly discuss the results.

V. Conclusion

In our research, we first took a look at the ISB definition and its characteristics. The Industrial Solutions Business is defined as a business concentrated on the development of industrial solutions and it has four features: large-scale, complex, inter-disciplinary and customer-need-specific.

The conducted literature review and interviews in Chinese industry raised the challenge list for ISB in China which covers 8 aspects and 22 challenges. The 8 aspects are planning management, quality management, knowledge management, technology management, complexity management, environmental management, risk management and others.

Currently there are some limitations of our research and we are still looking into the challenges to apply solutions for them. Therefore we will discuss the implications for research and enterprises in China. And finally we will think about the limitations and further research.

A. Implications for research activities and enterprises in China

The results are enlightening for both: further research on ISB standards and the enterprises in ISB area in China.

Regarding the first aspect, the results have provided a direction for study emphasis. The future standards should be

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able to answer the challenges, particularly for those emphasized by the project managers. For the challenge domains, best practices should be given to provide a reference of how to deal with these problems. Finally also brief use cases should be included to depict potential traps in these areas.

Beside the before stated points, for ISB enterprises in China, the results serve as a certain base line against which they could measure themselves.

B. Further work

The research does not focus on the following aspects; firstly the investigation has crossed several different industries. It is helpful to get the general prospective but this eliminates the unique characteristics of each industry. To get a better understanding of a certain industry, independent investigations should be carried out. This could be accomplished by a couple of interviews with professionals of this industry and then quantitative questionnaires distributed solely to the project managers in this domain. Secondly while the challenges of ISB have been identified, the practices to deal with them are not thoroughly studied. The best practices always come from industry reality. A further study of the solutions to these challenges proposed by project managers is therefore essential.

REFERENCES

[1] Frederik Ahlemann, Project management standards–Diffusion and application in Germany and Switzerland, International Journal of Project Management 27 (2009) 292–303
[2] Wei Wei, A Research on a System Development Process Model for Industrial Solutions, Thesis of Master, Tsinghua University, 2007
[3] PMI, A Guide to the Project Management Body of Knowledge, 3rd Edition, ANSI/PMI 99-001-2004, 2004
[4] Software Engineering Institute, Carnegie Mellon University, CMMI Version 1.2, http://www.sei.cmu.edu/cmmi/general/index.html, 2009
[5] Technical Report 2008 on ISB Research, project document, Tsinghua University, 2008
[6] Rosinski W.F., Development of a System Development Process Model for Systems Engineering in Industrial Solution Business: Mini thesis, 2007, Tsinghua University

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