Chapter 3
Methodology

3.1 Chapter Overview

This chapter is presented in two main parts. The first provides a conceptual overview of research framework, namely, the lean knowledge management approach to school safety. The second part of the chapter describes the research process in a step-by-step way, detailing each of the methodological steps. The rationale behind selection of particular research instruments and sample groups is also provided with these methodological steps. Each of the research steps is described to build an overall picture of the methodological process used in the research. Before these methodological steps are introduced, the chapter begins with the theoretical and conceptual standpoint behind the research, namely the justification and explanation of the knowledge management approach, and its synergy with lean thinking.

3.2 Conceptual Framework

Figure 3.1 shows the conceptual framework of the thesis, which is framed and underpinned by knowledge management. Figure 3.1 is split into two main areas, reflecting the tacit and explicit aspects of school safety. This is conceptualized by the iceberg model, which highlights the visible (explicit) and invisible (tacit) aspects of school safety that are addressed in the research methodology. In terms of the visible (explicit) aspects, Figure 3.1 shows that the methodology focuses on lean tools, including the seven wastes and 5S to streamline safety processes. The AHP model is also critical to reduce the complexity and burden of addressing school safety. The conceptual framework and its components are described below.

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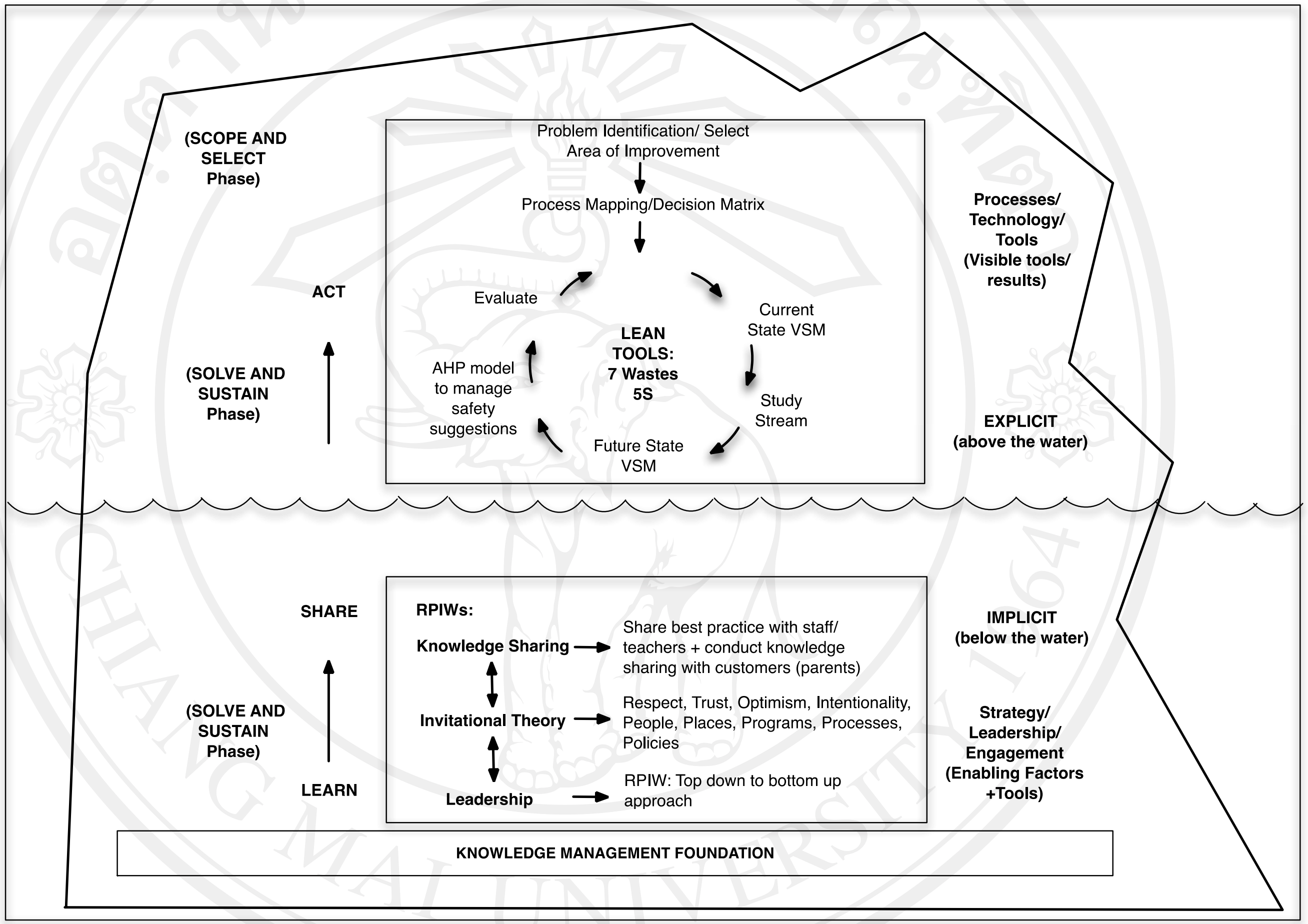

Figure 3.1 The conceptual framework of the research, including tacit and explicit aspects of the research, framed by a knowledge management approach

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3.3 A Lean Knowledge Management Approach to School Safety

Organizational learning is a collective process where ideas, concepts, facts, and traditions are transferred, transformed, and mobilized throughout an organization. Safety knowledge and learning is related to this organizational learning process (Gherardi and Nicolini, 2000), and the concepts and theories of knowledge management can be applied to the way in which the organization manages and uses its safety-related organizational leaning. The effective management of safety requires interaction, information, monitoring, status updates, awareness, and a repository of appropriate documentation and facts (Boy and Barnard, 2005). As such, the requirement for effective safety is matched by the proficiencies offered by knowledge management approach. Along with the transition to knowledge society, Hargreaves (1991) argues that there is an urgent need for increased knowledge management within schools. The school is an intrinsically knowledge-based environment, and while there has been significant recognition of KM in business, the importance of KM to schools has only recently been recognized (Petrides and Guiney, 2002). The knowledge management approach in this thesis therefore combines the knowledge requirements of safety with the need for better knowledge management in an educational setting. The result is a methodological concepts that uses Knowledge Management to synergistically create a new knowledge based approach to the management to school safety.

Lean thinking is combined with knowledge management to create an approach to problem solving where best practices can be shared and continuous improvement can be undertaken. Lean thinking has already been applied to schools in order to reduce budgetary constraints and improve school services, but it has rarely (if ever) been combined with knowledge management and applied to the problem of school safety. The overall methodological concept in this research is therefore to combine lean thinking and knowledge management as tools to solve the problem of school safety. Figure 3.2 illustrates how these concepts fit together. Lean thinking and associated tools are applied to the explicit visible processes in the school related to safety. In addition, knowledge management is applied to the tacit enabling factors contributing to school safety. Lean thinking and knowledge management are thus applied in synergy to the problem of school safety. Chapter 2 has already shown how school safety is strongly affected and meditated by budget, and thus lean thinking has potential to address safety issues elated to budget and time. Chapter 2 also explained how critical the enabling factors are to school safety, including aspects such as leadership and school culture. Figure 3.2 is conceptualized using the analogy of an iceberg, as the enabling factors are bigger and more difficult issues to address than the explicit visible aspects. Therefore while knowledge management and lean thinking

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are applied in synergy to the issue of school safety, knowledge management represents the central methodological tenet on which this work is based.

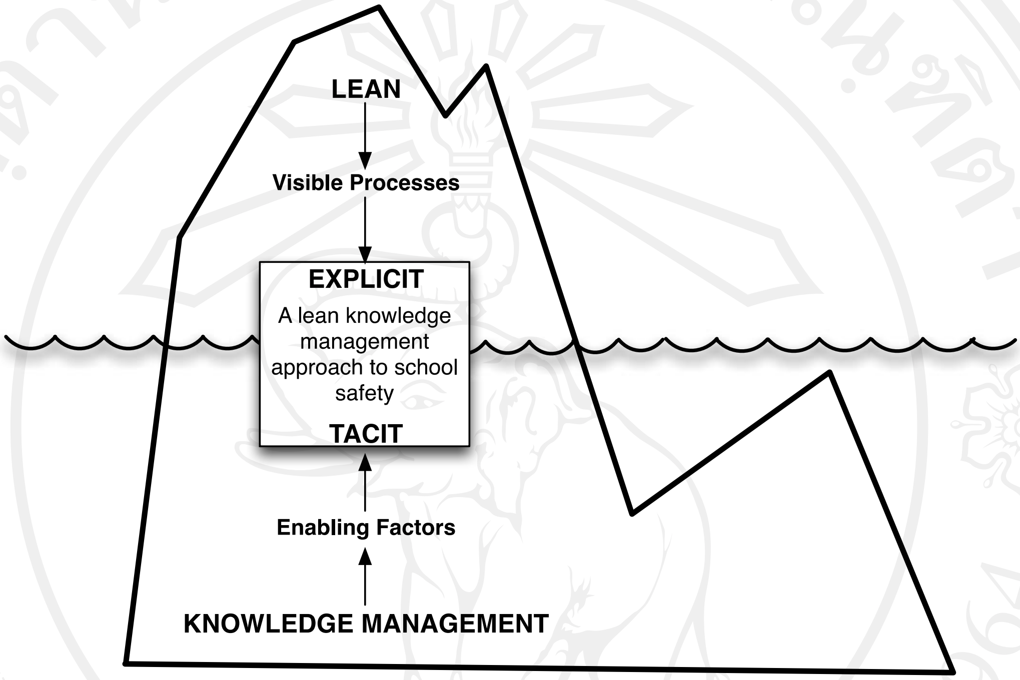

Figure 3.2 The conceptual synergy of lean and knowledge management to improve the approach to school safety

3.4 KM to Improve School Safety

While Chapter 2 (section 2.17-2.19) has critically analysed the field of knowledge management, the key precepts of knowledge management are now introduced in terms of their relationship with effective safety, and how knowledge management can be practically applied to effectively enhance the way in which safety is administered, particularly in a school-based environment. Some of the key principles in the field of knowledge management are introduced below and then explained with specific reference to their associated relationship with safety. The key strengths of KM are as follows:

- KM leads to increased organizational efficiency and Enhanced Organizational Productivity

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- KM focuses on the most important organizational assets (e.g. human capital)
- KM encourages collaboration and provides knowledge sharing tools
- KM can reengineer and/or reorient the organization's culture
- KM can improve decision making processes and speed
- KM can build insight and innovation

3.4.1 KM Leads to Increased Organizational Efficiency and Enhanced Organizational Productivity

The KM literature suggests that KM is a useful way to enhance an organization's efficiency (e.g. Fugate et al., 2009). In parallel to this notion, evidence suggests that organizational efficiency can have a significant effect on safety, but this effect is variable, and often intangible. For example, while an efficient approach to safety can have positive impacts, others report that there is an asymmetry between promoting safety and an organization's efficiency. Table 3.1 illustrates these asymmetries.

Table 3.1 The asymmetry between safety and organizational efficiency (adapted and modified from Aase et al., 2009)

The Asymmetry Between Safety and Organizational Efficiency		
Organizational Efficiency	**Gap (School Safety Requirements)**	**Safety**
• Efficiency can be measured through financial metrics and other tangible organizational results (e.g. revenue, earnings).	• Must ensure school safety is efficient and this efficiency can be shown in a tangible way	• Safety is often intangible and unsuitable for direct measurement meaning it is difficult to interpret.

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Table 3.1 The asymmetry between safety and organizational efficiency (adapted and modified from Aase et al., 2009) (Continue)

The Asymmetry Between Safety and Organizational Efficiency		
Organizational Efficiency	**Gap (School Safety Requirements)**	**Safety**
• There is positive reinforcement as efficiency increases within an organization – i.e. if efficiency is increased, earnings might increase or money might be saved meaning the relevance and positivity of efficiency is easy to see.	• Make the value of safety visible and ensure awareness of the link between school safety and the organization's overall effectiveness	• With safety, negativity becomes a sign of an effective safety regime. For example, no accidents or incidents might be a sign that safety is being effectively managed. The value of safety is sometimes difficult to see within an organization until there is an accident or near miss.
• The relationship between efficiency and the effort/resources placed into creating efficiency is clearly defined and visible.	• Ensure the relationship between organizational effort/efficienc y, and school safety is made explicit	• The relationship between effort/resources and the effect on safety is not certain.

Table 3.1 highlights the traditional issue with safety and organizational efficiency. While safety is often considered as hindering efficiency, it is a critical past of a school environment and Knowledge Management's strength in creating an efficient organization, can be applied to school safety. Safety at school is often neglected due to fiscal demands and the opportunity cost of spending on safety versus other school aspects (e.g. academic matters). Thus a KM approach to school safety is efficient, as well as important. KM's approach to organizational and safety efficiency is enhanced and extended via the synergy with lean thinking.

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3.4.2 KM Focuses on the Most Important Organizational Assets (e.g. Human Capital)

Safety is intrinsically related to people, both in terms of how they affect safety, and the potential impact safety has upon them. The way in which individuals act has a direct influence on safety, and therefore KM's focus on human capital and people has a direct link with safety. The foundation of KM is often people (Wiig, 1993) and therefore people acts as a common link between the fundamental aspects of KM, and the central aspects of safety in a school. In this research, the use of KM is as an enabling factor, in order to ensure human capital is utilized correctly and understands/focuses on safety.

3.4.3 KM Encourages Collaboration and Provides Knowledge Sharing Tools

Effective safety relies on sharing safety related knowledge, and collaborating across the organization to ensure a safe environment. According to Knuth and Brooks (2006), knowledge sharing for school safety is of paramount importance, and requires knowledge sharing to become a core management value. The use of a knowledge management approach in this methodology is therefore ideally suited to school safety, as knowledge management provides the appropriate philosophies and instruments to develop an effective approach to knowledge sharing. This research capitalizes on these aspects of KM to ensure knowledge sharing is a core part of school safety.

3.4.4 KM can Reengineer and/or Reorient the Organization's Culture

The importance of culture to effective safety is well described, both in terms of an individual organization's culture, and the wider effect a nation's culture can have upon safety. Safety culture is an important sub-facet of the overall organizational culture (Cooper, 2000). Chapter 2 (section 2.17-2.19) elaborated how school safety varies depending on the particular country, which is in turn related to the culture of that particular country. Culture is described as an attitude, orientation or set of values (Swidler, 1986) and has a significant impact on safety (Guldenmund, 2000). Some argue that KM is rooted in a need for change and can be practically applied to create effective change in various organizations (Davenport et al., 1997). This ability to drive change and reorient an organization is harnessed in the concept of this work, which reorients the culture in the case study school to

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ensure safety and its management are effective. In this study, KM is utilized to approach the culture in the school and reorient it towards more effective management of safety.

3.4.5 KM can Improve Decision Making Processes and Speed

Safety is often about decisions (Lowrance, 1976). In the school environment a variety of decisions about safety must be made on a day-to-day basis. For example, parents frequently contact the school to suggest new safety measures, or question the current ones, and in turn, school management must carefully consider these. There are also safety decisions related to the school's safety policy, the roles and responsibilities of everyone in the school regarding safety, and the budget spent on safety. According to Courtney (2001), organizational decisions are a complex mix of social, environmental and economic concerns, and knowledge management represents a new decision making paradigm. In this research, the decision making power of KM is utilized via capturing appropriate safety knowledge, ensuring this knowledge is shared, and building a decision support system to effectively structure the decision making processes related to school safety. Thus the research in this thesis not only brings together the organizational learning and human aspects of knowledge management, but also utilizes the more technical aspects of KM in building a decision support system.

3.4.6 KM Can Build Insight and Innovation

As discussed in Chapters 1 and 2, in a private school, safety is not just important for issues of morality and compliance, but it also has significant impacts on the parents of the school, and the school's ability to attract and retain students. The ability to attract and retail students translates into competitive advantage in an increasingly competitive education sector. Similarly, KM provides the appropriate tools for organizations to capitalize on their knowledge and extract value from this knowledge (Gold et al., 2001), thus providing an organization with insight and the ability to innovate. In this thesis, KM is used to capture and organize safety knowledge so that it can be utilized to enhance the school's approach to safety and ultimately, increase parental (customer) satisfaction with the school.

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3.5 Lean Thinking for School Safety

While KM is shown in Figure 3.2 to be related to the tacit and invisible aspects of safety in the school, such as the tacit knowledge people hold about school safety, and the school's culture and leadership, school safety is also about the visible, explicit processes in the school. Chapter 2 has already introduced and described lean thinking as a process reengineering methodology, which has been successfully applied to a number of organizations operating in different sectors. With specific reference to safety, lean thinking has improved the quality of care and safety of patients in the healthcare sector. In this research, lean thinking is used as a process reengineering methodology to enhance the processes related to school safety, and is applied in conjunction with the other more tacit aspects of school safety. Chapters 1 and 2 have already outlined the key issues of cost associated with school safety, and lean thinking is therefore applied in the research to meet the requirements of school safety against a strained budget. Lean is therefore about the explicit, visible processes related to safety, while KM acts as the foundation of the research and focuses on the tacit factors associated with school safety. The application of KM and lean thinking to school safety is undertaken via a case study approach at a case study school in northern Thailand.

3.6 The Case Study: A Private Primary School in Northern Thailand

Figure 3.3 shows the location of the case study, which is a private school in northern Thailand, approximately 30 minutes by car from Thailand's largest northern city (Chiang Mai). The school has been operational for 25 years, and aside from a high quality education, parents expect their children to be safe. The school runs kindergarten and primary level education programs, and is well known among parents in its catchment area. With 1,420 students on roll, including 451 in kindergarten, 969 primary students, and 98 teachers and administrative staff, safety is a significant issue of concern for the school and its reputation.

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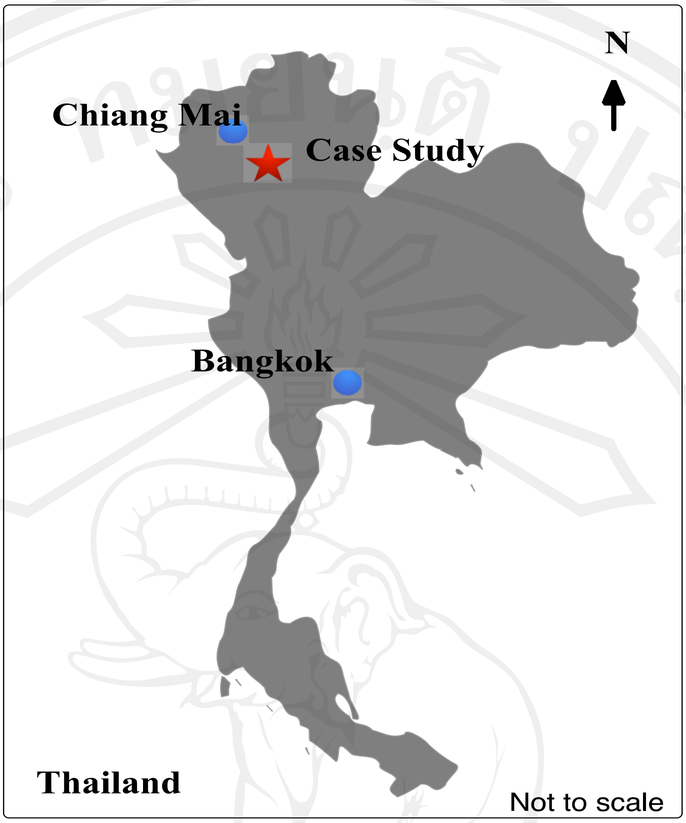

Figure 3.3 The case study school

3.7 The Scope, Select, Solve, Sustain Methodology

To achieve the aims and objectives set out in Chapter 1, the scope, select, solve and sustain methodology was followed. Figure 3.4 illustrates each of these four phases, which are now explained along with the associated data collection and instruments for analysis.

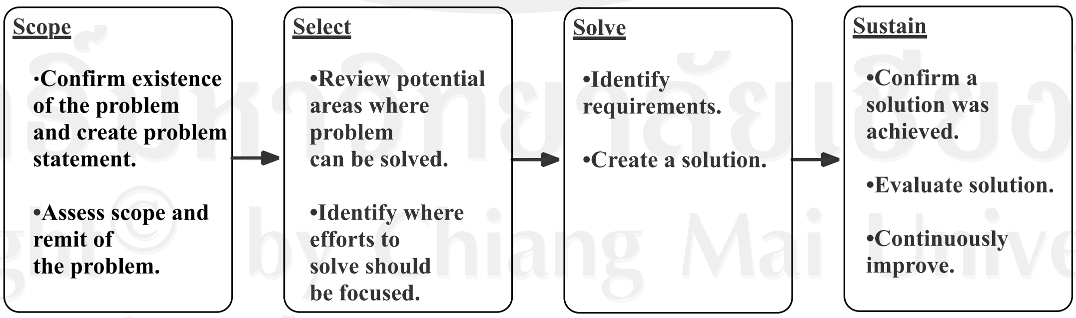

Figure 3.4 The four phases of scope, select, solve and sustain, which were followed in the methodology

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According to Figure 3.4, scope is about determining the remit of the research problem, while the select phase focuses on the particular case study and assesses which areas should be focused on at the case study. Solve represents the main part of the research and is to solve the research problem identified in the scope and select phases. Sustain is the evaluation section of the methodology, which seeks to evaluate the solution and then ensure the solution is sustained. The scope, select, solve and sustain methodology can be linked to the plan, do, check, act steps of the Deming cycle, as shown in Figure 3.5.

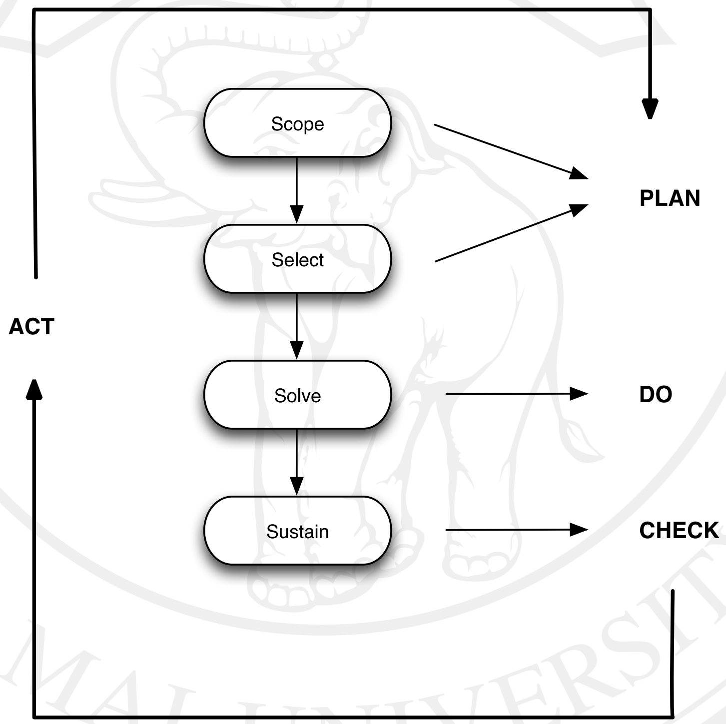

Figure 3.5 The scope, select, solve and sustain methodology and its relationship with the Deming cycle

- Each of the four scope, select, solve and sustain phases of the methodology have associated knowledge management and data collection aspects. Figure 3.6 illustrates the four phases of the methodology together with the data collection at each step and how this relates to the overall knowledge management framework.

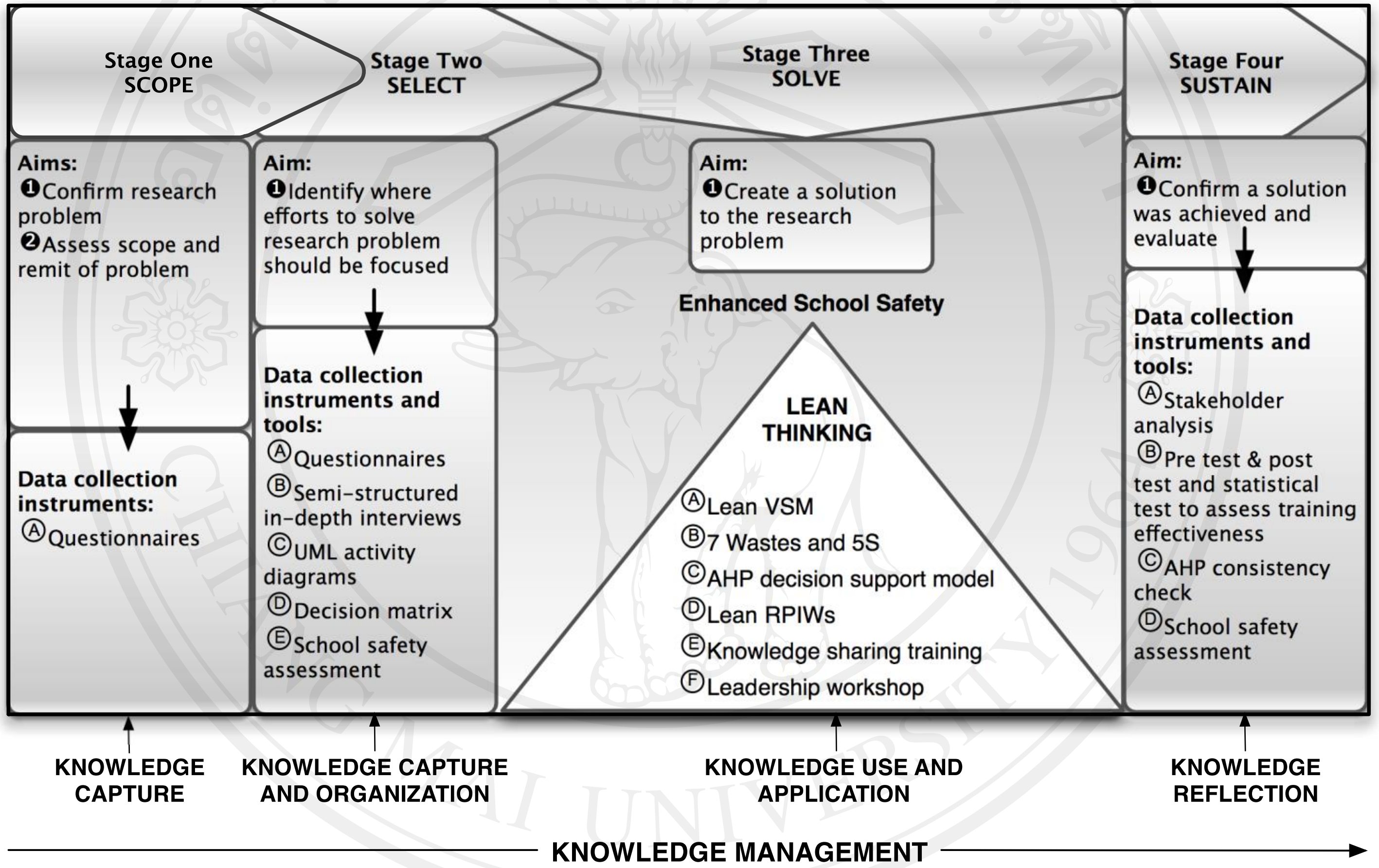

Figure 3.6 The four phases of the methodology along with data collection and the relationship to the overall knowledge management framework

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Figure 3.6 shows that during the first scope phase of the research, there are two main aims, which are to confirm and understand the research problem, and assess and understand the remit of this problem. In terms of knowledge management, this phase is associated with knowledge capture, and uses questionnaires as the main data collection instruments.

The second phase of the methodology is the select phase. This phase has one overall aim, which is to identify where the efforts to solve the research problems should be focused. More specifically, this phase is associated with understanding the current situation of school safety at the case study so that an effective solution can be designed and implemented. Figure 3.6 illustrates that there are five key data collection instruments (labeled from A – E in Figure 3.6) during this stage of the methodology. The first two (A, B) are related to knowledge capture, and consist of further questionnaires as well as in-depth interviews. The second aspect of this phase is the focus on school safety processes, and for this, UML activity diagrams are used to map the school's current safety processes, while the subsequent use of a decision matrix enables the research to select which aspects of the school's safety to focus on. The final data collection instrument of this select phase, is a school safety assessment, which is used to provide a benchmark of the case study school's safety prior to the design and implementation of a solution, and thus contributes to later evaluation of the research.

Stage three of the methodology is shown by Figure 3.6 to be the solve phase. This phase is perhaps the most important of the research, and shows how a solution to the research problem was designed and implemented. While there is one key aim to this phase, which is to create a solution to the research problem, a variety of research instruments were used. In terms of explicit aspects of school safety, these include the application of lean value stream mapping (VSM), the use of the seven wastes approach to reducing waste associated with safety processes, 5S to sort and standardize safety processes and then AHP to create a decision support system related to the school's continuous receipt of safety suggestions from parents. For the tacit aspects of school safety, lean rapid process improvement workshops (RPIWs) were held with school staff to improve school safety, as well as leadership training and knowledge sharing awareness workshop. Thus in this phase of the research, both the tacit and explicit aspects of school safety were targeted by the methodology.

Figure 3.6 shows that the final stage of the research was the sustain phase. This phase was associated with evaluating the research solution and assessing the effectiveness of the new approach to school safety. The overall aim of this phase was to confirm that a solution had been achieved, and then evaluate that solution. In terms of data collection instruments, the key evaluation took place through an analysis of stakeholders' views, attitudes and opinions to the new approach to school safety.

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While this approach is generally qualitative, there were also some quantitative aspects to the evaluation, including a pre and post test to assess the effectiveness of staff training, as well as a statistical analysis of the differences before and after training. There was also a consistency check of the AHP decision support model, to ensure that it delivered consistent and usable results, and then a final school safety assessment, which was compared with the earlier safety assessment from the select phase in order to assess how school safety had changed after the research solution had been implemented.

Each of the four scope, select, solve and sustain phases are now explained in detail, along with a thorough explanation of the data collection instruments and analysis techniques.

3.7.1 Scope Phase (Problem Identification and Research Justification)

The first phase in the research was the scope phase. This was undertaken to assess the scope of the research problem, before moving to focus on specific aspects of school safety at the case study. Figure 3.7 illsutrates the scope phase, along with the key data collection instrument, which was questionnaires sent to five schools in northern Thailand.

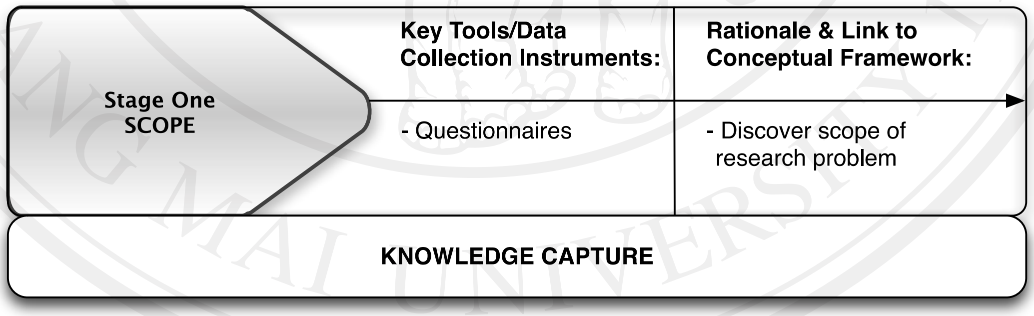

Figure 3.7 The scope phase of the research, and the related tools and rationale.

As noted above and shown in Figure 3.7, this phase was important to effectively identify the research problem, assess its remit, and determine the overall scope of the research problem. In short, this phase was about problem identification and research justification. There were two main tasks within the scope phase:

Tasks:
1. Confirm/identify the research problem of safety at school
2. Assess the scope and remit of the research problem

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These tasks were enabled via the following data collection instruments:

Tools and Rationale:

1. Questionnaires at five schools in northern Thailand. This allowed aside range of opinions and attitudes toward safety to be gathered to assess the problem scope.
2. Literature review. This has been presented in Chapter 2, however results from the literature helped inform this stage of the research and drive design of the school questionnaires.

The questionnaire consisted of 16 questions related to school safety. The survey was created based on the International Alliance for Invitational Education's (IAIE) Revised Inviting School Survey (ISS-R) (2012). The inviting school survey is based on the Invitational Theory of Practice (ITOP), which has already been detailed in Chapter 2, and has been continuously developed and applied to create safer and more inviting schools since its introduction (e.g. Juhnke and Purkey, 1995; Lehr, 1999; Lehr and Eubanks, 1997; Novak, 2002; Purkey, 2000). The ISS-R (2012) is based on the notion that school climate heavily affects student achievement and success, and is based on a personal evaluation of the school. Therefore, the questionnaire sent to the sample groups described in Table 3.2, sought to gather a personal evaluation of their school and their associated opinions and attitudes towards the school and its safety. During analysis of the questionnaire responses, the range and frequency of responses was assessed to understand the general attitude and opinions to school safety in Thailand, particularly between parents from different school types, for example primary versus secondary, and government versus primary.

The questionnaire in this research is shown in Appendix A, however, in summary, the questionnaire was split into two main sections. These were:

1. **General attitudes toward safety** – this part of the questionnaire focused on general attitudes of the respondent to school safety in Thailand, such as how important the respondent felt school safety was.
2. **Opinions of the school** - this section of the questionnaire related specifically to the respondent's (parent, staff or teacher) school. Questions included how safe they felt their school was, and other aspects relating to the safety of their school.

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To achieve these tasks, data collection at this stage focused on questionnaires at five different types of school, and from three main school stakeholders. The sample groups in terms of the schools chosen for data collection and the respondents are shown in Table 3.2.

Table 3.2 The five sample group details (schools)

Sample group details	Respondents		
1. Government primary school in Lamphun – operating in Lamphun only at the primary levels (P1 – P6). There are approximately 150 students, 22 teachers and 19 staff.	**Parents**	**Teachers**	**Staff**
2. Private primary school in Lamphun (a). This is a private primary school (levels P1-P6) with approximately 806 students and 60 teachers and staff.	**Parents**	**Teachers**	**Staff**
3. Private primary school in Lamphun (b) with 840 students and 93 teachers/staff.	**Parents**	**Teachers**	**Staff**
4. Government secondary school in Lamphun. This is a large government secondary school (levels M1-M6) operating in Lamphun, with 259 teachers/staff and approximately 3300 students.	**Parents**	**Teachers**	**Staff**
5. Private secondary school in Lamphun providing education from M1-M3 with 420 students and 36 teachers/staff.	**Parents**	**Teachers**	**Staff**

According to Babbie (1990, 2001), the response rates are acceptable given the purpose of the survey, and the way in which the survey was distributed (i.e. passed to the schools with no monetary incentive to return them).

The questionnaires were analyzed using simple descriptive statistics and graphs in order to understand the frequency of responses and the scale of attitudes and opinions toward safety in Thai schools. Bar graphs were the primary mechanism for analysis as they allowed a quick and easy

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visualization of attitudes and opinions toward school safety. The analysis focused on understanding the degree of importance parents placed upon school safety in Thailand, as well as the different attitudes and opinions between teachers and parents, the differences between government and private schools, and the differences between primary and secondary schools.

To ensure that the responses of parents at the various schools were consistent/honest, a mechanism was built into the questionnaires to calculate the honesty score for each sample group (school). By placing two identical, but separate questions on the survey, the consistency and honesty of respondents could be measured. Those respondents who were answering properly by reading the questions, and remaining honest in their responses should provide the same response to these two questions. Therefore the responses for each of the two questions can be compared and correlated to calculate the degree of agreement (consistency) in responses. Following analysis of these questionnaires, the extent of the research problem could be effectively understood, and the next phase focused on the case study school to understand in detail the issues of school safety and how to most appropriately address these.

3.7.2 Select Phase (Problem Focus at the Case Study School)

This stage was to identify and select where research efforts should be focused to solve the problem identified in the earlier scope phase. Figure 3.8 indicates that the key tools and data collection instruments in this phase were a further set of questionnaires, in-depth interviews, and UML diagrams.

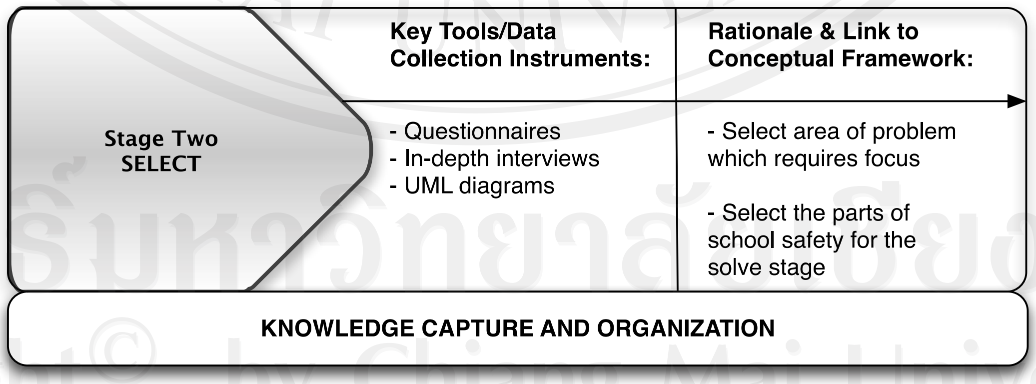

Figure 3.8 The select phase along with related tools and rationale

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Specifically, this phase focused on the case study school. There were three main tasks in the select phase, as follows:

Tasks:

1. Identify areas where research efforts should focus.
2. Select which parts of the case study focus on driving the solve phase.
3. Decide the area and the process to be followed during the solve phase.

These tasks were met through the following research tools and data collection instruments:

Research Tools and Rationale:

1. Questionnaires to understand the range of opinions and attitudes regarding the issue of safety at the school
2. Semi-Structured in-depth interviews to understand the depth of feeling and attitude toward school safety
3. UML activity diagrams to understand and select the safety processes requiring attention
4. Decision matrix based on the UML diagrams to select which visible (explicit) processes to focus on in the solve phase

These research tools are now described in detail in terms of the data collection instruments and analysis.

3.7.3 Questionnaires to Understand Range of Opinions and Attitudes

These questionnaires were different from those in the scope phase and were undertaken to gain a detailed understanding of how the main school stakeholders viewed safety at the case study school. The sample size was expanded, and the questionnaire itself was adapted to gain further insight into the case study school and the respondents attitudes and opinion to school safety. As with the questionnaires in the scope phase of the methodology, the questions were adapted from the ISS-R and then translated into Thai.

In a similar fashion to the questionnaire in the scope phase, parents, teachers and staff were questioned relating to their general attitudes and opinions toward school safety, as well as their specific feelings toward school safety at the case study school. There were four main sections in the case study questionnaire. These were:

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1. **General attitudes toward safety** – as with the scope phase questionnaire, these questions pertained to the general attitude of teachers, parents and staff attitudes toward safety.
2. **Opinion of safety at the case study school** – these questions were about the attitude and opinion of school safety, but with specific reference to the case study school.
3. **Assessment of the areas in the school which are considered unsafe** – this part of the questionnaire sought to understand the attitudes of respondents with regard to the areas of the school they felt were particularly safe or unsafe. The rationale behind this section of the questionnaire was to understand which parts of the school required focus in terms of improving safety and value to parents.
4. **An assessment of knowledge sharing practices in the school** – respondents were also asked a series of questions related to knowledge sharing in the school, with particular reference to knowledge sharing related to safety. This was to understand how the case study school is currently performing with regard to knowledge sharing of safety related knowledge. This was important to understand the link between safety related knowledge in the school and the critically important process of sharing such knowledge.

The questionnaires in the select phase were analysed in the same way as those from the scope phase. This meant an honesty score was computed, and bar graphs and general descriptive statistics were utilized to understand the attitudes and opinions towards safety, the areas of the school requiring focus (including whether these were physical or intangible aspects of the school's safety), and finally, the state of safety related knowledge sharing in the school. Together, the responses and analyses of these questionnaires provided an understanding of the range of opinions and attitudes toward school safety, and how safety related knowledge was shared among parents, teachers and staff. The next step was to build on this breadth of understanding through in-depth semi-structured interviews, so that depth, as well as breadth of understanding could be achieved at the case study school. This ensured an appropriate solution was designed and implemented in the solve phase.

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3.7.4 Semi-Structured In-Depth Interviews

While the questionnaires described above in sections 3.7.2 and 3.7.3 were about understanding the range of opinions and attitudes toward safety at the school, the in-depth interviews allowed for the depth of opinion to be assessed, and to elaborate on the answers given in the questionnaires. Interviewees were chosen at random from three main sample groups: parents, teachers and staff. Five interviewees were selected from each sample group, meaning there were five teachers, five staff, and five parents. Each semi-structured interview lasted approximately one hour, and followed the general format recommended by Lederman (1990). There were four main stages during the interviews: warm-up, discussion, focus, and revise. These four steps along with their main purpose are shown in Figure 3.9.

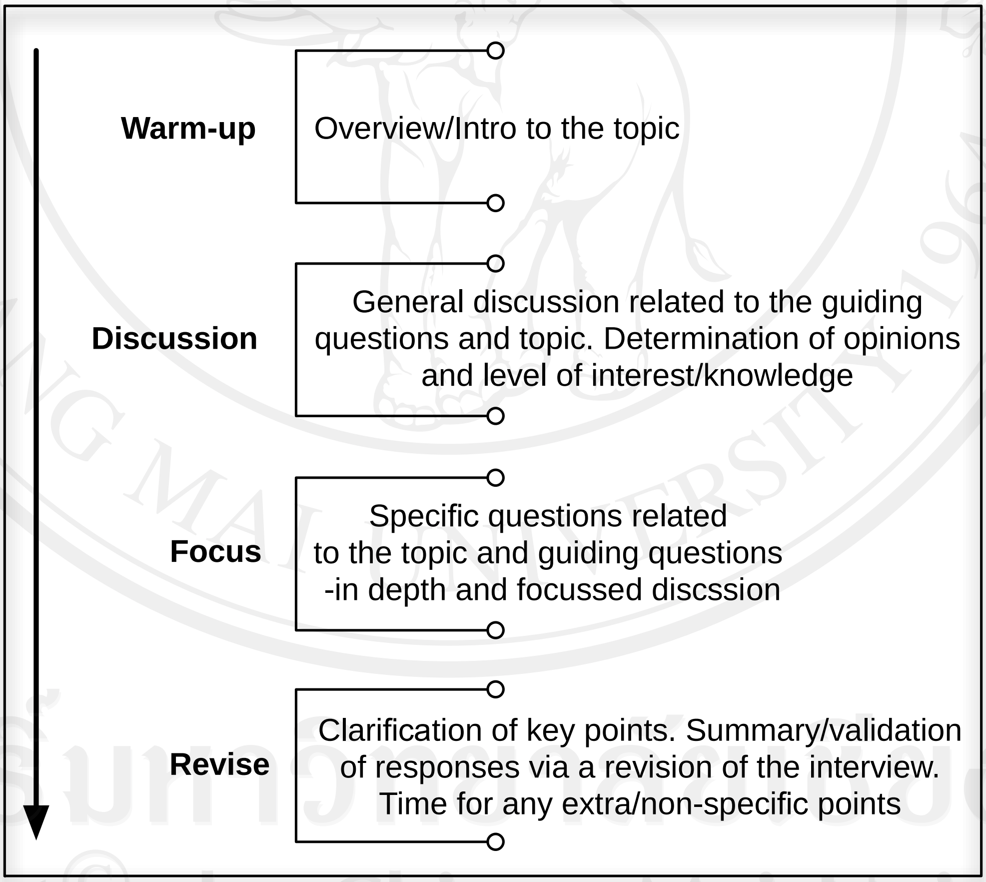

Figure 3.9 The four steps followed during the in-depth interviews

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- Warm-up allowed the interviewees to relax prior to being questioned and served to introduce the context of the questions.
- Discussion took place to determine participants' opinions and level of interest in the topic.
- Focus was the period of the interview where specific questions related to the topic were asked.
- Revise served as a conclusion to the interview, and allowed a reiteration of key points as well as the addition of any further relevant comments.

The interviews followed a set of guiding questions, which were formulated based on invitational theory (Purkey, 1992). As detailed in Chapter 2, invitational theory suggests that there are five critical aspects to a welcoming and safe school (people, places, programs, policies, and processes) (Stanley et al., 2004). As such, these five aspects were used as a basis to structure the interviews and provide guiding questions. Table 3.3 illustrates the matrix created for the in-depth interviews, which was used during the interviews to probe the interviewees and provide guidance so that the appropriate knowledge could be captured from the interviewees. The matrix shown in Table 3.3 is based on the five key principles of invitational theory and includes questions related to safety in the categories of people, place, programs, policies and processes.

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Table 3.3 Semi-structured interview matrix based on invitational theory and adapted to school safety at the case study

People	Places	Policies	Programs	Processes
• Are people aware of safety as an issue at the school? • How do people affect safety at the school? • Who are the key stakeholders of school safety? • Are there any individuals with specific safety responsibilities? • Is everybody involved in safety at the school? • Does safety add to the workload of teachers, staff, or administrators? • What is the role of teachers, staff and school leaders in safety? • Do you have any other comments?	• Are there any places in the school that are particularly safe or unsafe? • Does the school offer an attractive and pleasant environment – please say why or why not? • What do you think could be done to improve safety within the school environment? • What are the classrooms, bathrooms and offices like at the school? • Why do you think the school environment is safe/unsafe? • Do you have any other comments?	• What safety polices does the school have in place? • Are the school safety policies effective? • How are the school safety policies/guidelines designed? • How do the school safety policies/guidelines meet governmental policy/guidance? • Does the school regularly review and update its safety guidelines/policies? • Do you have any other comments?	• Does the school have any special safety programs in place? (e.g. healthy eating, supervision at break times, security guards) • Do you think any specific safety programs are needed? • Do issues of safety affect or impact other programs in the school (e.g. sports, summer camp, field trips) • Do safety programs take much money or effort from other areas of the school? • Do you have any other comments?	• What safety related processes currently operate in the school? • Are there any particularly effective or ineffective safety processes in the school? • What safety processes or actions do you want to see in the school? • Do safety related processes have an impact of cost or operations in the school? • How are the safety processes in the school designed and by who? • Is everybody aware of the school safety processes? • Do you have any other comments?

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After the in-depth interviews, and prior to the solve phase of the research, a school hazard assessment was undertaken to understand areas of the school requiring focus, and to link these with the other data gathered so far during the select phase. The hazard assessment also enabled a snapshot of the current state of school safety (in terms of physical, tangible aspects), which could then be reassessed after the implementation of the solve phase to evaluate the effectiveness of the solution.

3.7.5 School Hazard Assessment

After gathering views from the parents, teachers, and staff via the questionnaires and in-depth interviews, the perspective of the school management was gathered in the form of an overall school safety assessment. This allowed a benchmarking of the current state of the school's safety prior to the implantation of any solutions. The school safety assessment was performed with the school director, manager and two safety managers.

The school director, manager and safety managers completed the school hazard assessment by walking around the school and completing an assessment sheet. This assessment sheet was based on the UNISDR (2011) One Million Safe Schools initiative, and included four sections, as follows:

- The entrance to the school
- The school buildings and grounds
- Systems procedures and skills
- The educational/school curriculum aspects of school safety

In total, there were 26 assessment questions in the school safety assessment, and the assessment pro forma is shown in Appendix A The results from this hazard assessment, along with the questionnaires and interviews, formed a benchmark of the school's current safety status. The next stage of the research sought to systematically and explicitly map out all the safety related activities in the school, so that the appropriate processes could be focused on during the solve phase. This explicit mapping took place via UML activity diagrams, which detailed all safety related activities in the school.

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3.7.6 UML Activity Diagrams

Once the state of safety attitudes and opinions had been captured via the questionnaires and in-depth interviews, the school processes and management burden related to school safety was assessed through Unified Modeling Language (UML) activity diagrams. The creation of UML activity diagrams at the case study allowed all the safety processes and the actors at the school to be identified. UML activity diagrams are a graphical representation of workflows, usually created in a stepwise fashion from the beginning to the end of a process. The UML diagrams include the initial state, final state, and the interim activities and decisions within the workflow/process. Figure 3.10 illustrates the key UML syntax used when creating the activity diagrams.

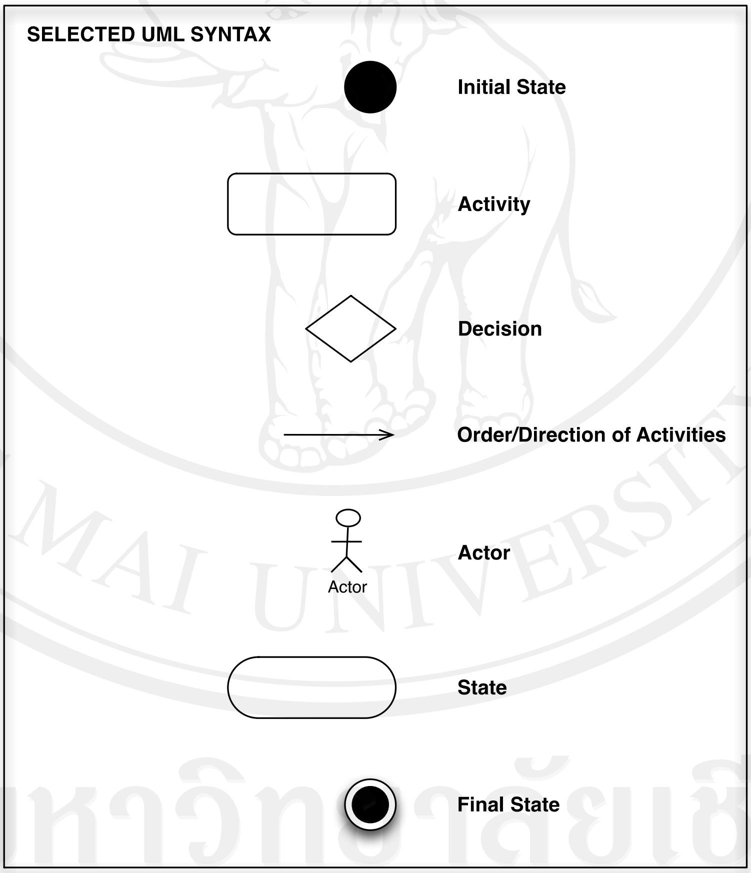

Figure 3.10 The UML syntax used to create
the UML safety activity diagrams at the case study school

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Creating UML activity diagrams allowed a full understanding of all the safety processes, activities and actors at the school. These UML diagrams were then scrutinized to identify the processes that represented the highest management burden, and required the most urgent attention. In consultation with school management at the case study, managing safety at the school was separated into five key areas. These were as follows:

- **Students' safety from morning until evening** – this activity diagram was created to show the activities required to ensure students' safety throughout the school day.
- **Responding to the needs and suggestions of parents** – this activity diagram was created to show how parents' safety suggestions were responded to by the school.
- **Safety budget and planning** – the activities the school undertakes with regard to budgeting and planning for safety were captured and organized in this diagram.
- **Safety compliance** – this UML diagram captured and illustrated the activities required to meet the various governmental compliance aspects of school safety in Thailand.
- **School safety monitoring** – the activities captured and presented in this diagram relate to the school's task of continuously monitoring the safety situation at the school.

Once these five UML activity diagrams were completed, they were assessed via a decision matrix in order to select which areas in the school should be focused on in the research. Analysing and selecting areas for focus is in keeping with the lean thinking approach in this thesis, which suggests problem-solving attention should be prioritized and focus on selected areas first, rather than attempting to solve all problems simultaneously. The fuzzy application of lean thinking across school safety boundaries is not conducive to reducing waste and improving value (Hines et al., 2004). The decision matrices thus enabled the research to select the most appropriate areas of school safety to focus on during the first part of the research.

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3.7.7 Decision Matrix

As noted previously, once the UML activity diagrams had been completed, there was a requirement to select areas for focus in the solve stage. This is in alignment with the overall lean thinking philosophy of the research, which recommends that certain areas should receive priority and focus, rather than following a scattershot approach by attempting to immediately solve every problem. The decision matrix was built based on how much management effort was required for each safety activity. The management effort for each activity was scored based on seven management areas affected by safety, as introduced in Chapter 1. These seven areas are as follows:

1. Finance
2. Time
3. Leadership
4. Communication
5. Stakeholder understanding
6. Culture
7. Commitment

The seven areas affecting safety were based on a literature review and discussion with school leadership at the case study. For each UML activity diagram, every individual activity was scored from 1-10 in each of these seven categories. The scoring process allowed a matrix to be built, which lists every school safety process, along with a management impact score. The scores were summed and converted to an overall management percentage.

		Management Scoring							Management	
ID	Activity	Finance	Time	Leadreship	Communication	Stakeholder	Culture	Commitment	Total	%
5001	Thai nationnal education policy	5	2	10	9	9	5	8	48	68.57
5002	Thai minstry of Education Private School Ac	5	2	10	9	9	5	8	48	68.57
5003	School policy	9	2	8	3	10	5	7	44	62.86
5004	School requirement	9	2	8	3	10	5	7	44	62.86
5005	Project	10	4	10	5	10	8	7	54	77.14
5006	Implement & maintain	10	10	10	10	10	5	8	63	90.00
5007	Monitor	10	10	10	10	10	5	8	63	90.00
5008	Government evaluation	8	3	10	10	10	2	8	51	72.86
5009	Improve	10	10	10	10	10	5	8	63	90.00

Figure 3.11 The example of the scoring matrix

Figure 3.11 illustrates an example of the scoring matrix showing the score for each of the activities in the compliance UML diagram and the associated management scores across the seven criteria. It also shows an example of the corresponding UML diagram.

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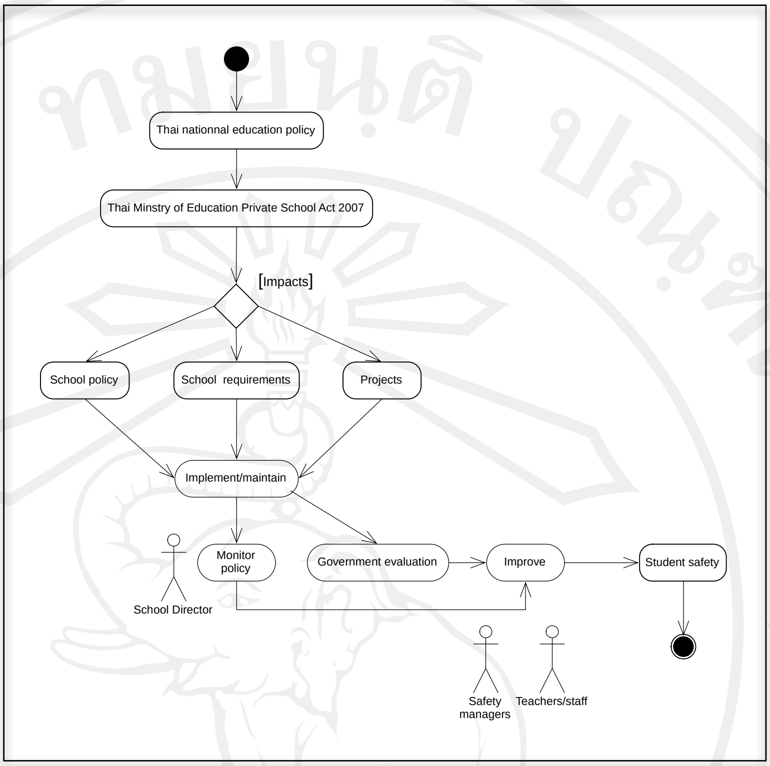

Figure 3.12 An example of the scoring matrices completed to understand the management effort required for the activities identified in the UML diagrams along with the corresponding UML diagram

Overall, there were 75 individual activities related to safety in the school. These were ranked based on their management score. Figure 3.12 gives a generalized example of this ranking process and illustrates the 75 safety related processes based on the management intensity/burden and represented by the percentage score. A higher score means that more management effort is needed to undertake the particular activity.

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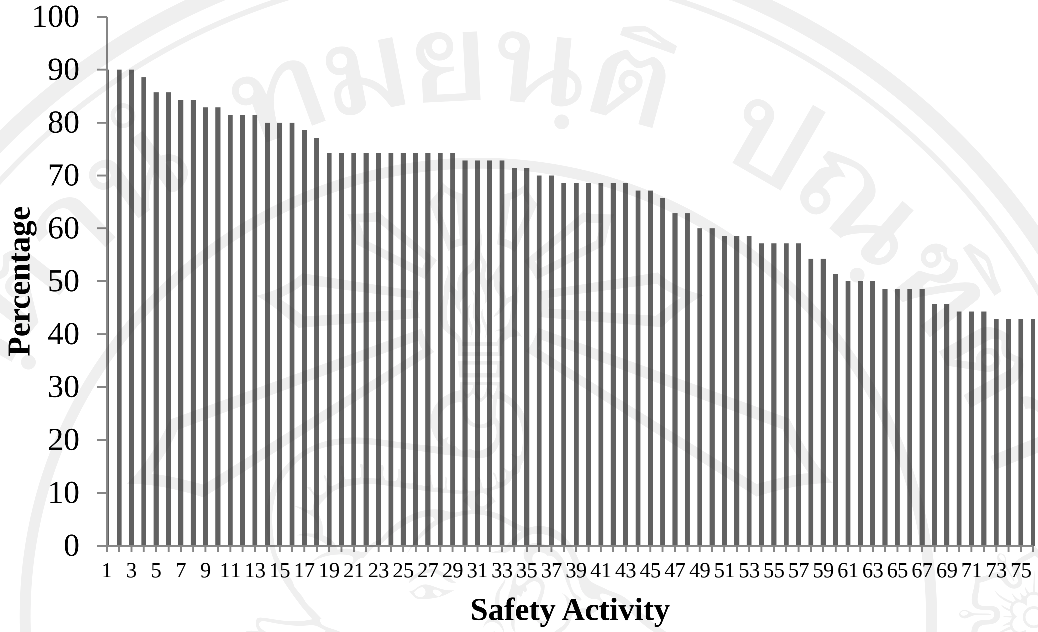

Figure 3.13 General representation of the 75 safety processes ranked according to the management effort required

Once these activities has been ranked according to their management intensity/burden, then the UML activity diagrams representing the management burden were selected for focus in the solve phase.

3.8 Solve Phase (Creating a Solution)

The solve phase is fundamental to the research presented in this thesis, and to achieving the aim and objectives set out in Chapter 1. This phase of the methodology is the most complex, as it represents the solution to the research problem and builds upon the results from the scope and select phases. Figure 3.14 shows both the tacit and explicit data collection instruments, and the key tools in this phase of the research.

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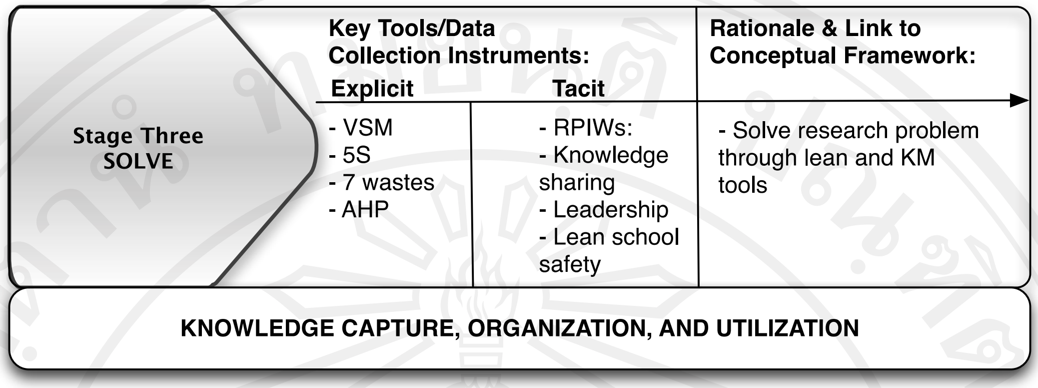

Figure 3.14 The solve phase of the research and the related tools and rationale

The key task of the solve phase along with the research tools and rationale are described as follows:

Task:

1. To solve the research problem identified in Chapter 1 and elucidated in the scope and select phases

To achieve this task, the following explicit and tacit research tools and data collection instruments were used:

Research Tools and Rationale:

Explicit:

1. Lean value stream mapping (VSM) to improve the efficiency and increase the value added time of key safety processes in the school.
2. 7 wastes and 5S to eliminate waste and improve school safety.
3. Analytical Hierarchy Process (AHP) to effectively and efficiently manage the school safety suggestions from parents.

Tacit:

1. Lean Rapid Process Improvement Workshops (RPIWs) to improve people in the school and their impact on safety.
2. Knowledge sharing training/activities to develop Knowledge Sharing in the school related to safety.
3. Leadership workshop to shift management empower staff at the school in terms of safety.

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The solve phase was approached from two main perspectives, the tacit/enabling factors and the explicit processes and tools. These two perspectives thus form the structure for the solve phase and its methodology. Figure 3.15 illustrates these two parts of the solve phase.

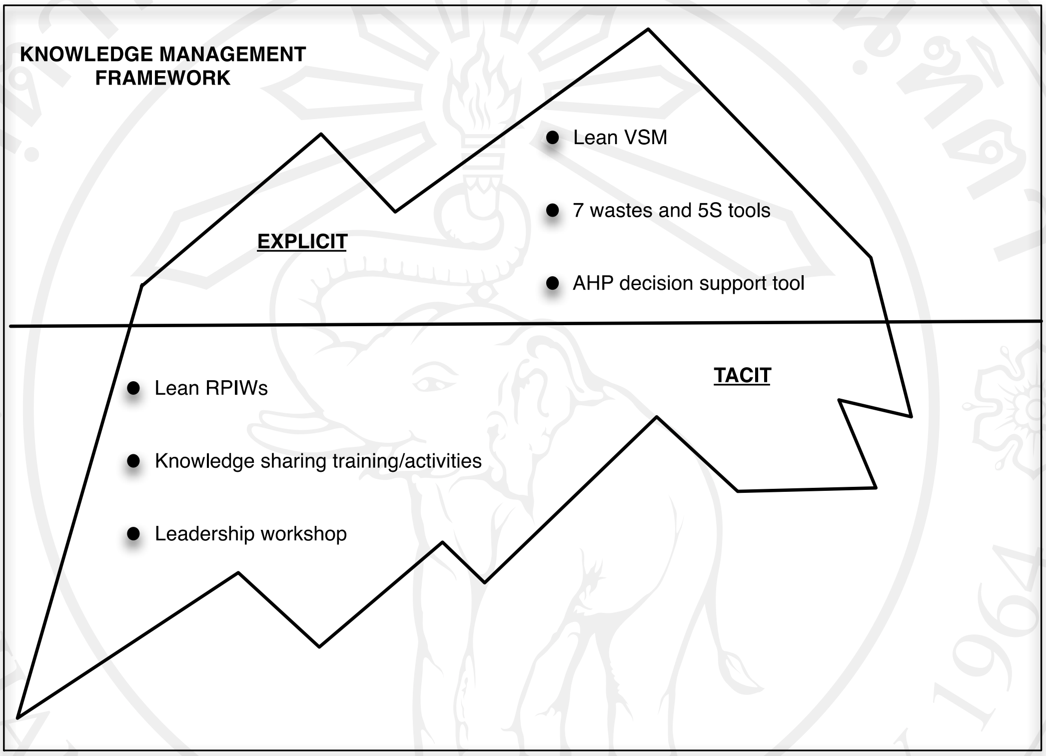

Figure 3.15 The framework for the solve phase of the methodology, which follows the iceberg model introduced in section 3.2

The methodological tools in Figure 3.15 are now introduced according to the two parts of the iceberg model: firstly the explicit/visible parts of the model, and secondly, the tacit/enabling factors.

3.8.1 Explicit/Visible Processes and Tools

The explicit processes in the methodology consisted of three main tools: lean value stream mapping, a decision support model based on the analytical hierarchy process (AHP), and finally an analysis of the processes in the school using the seven wastes and 5S methodologies. The methodology behind each of these tools is now explained in detail.

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3.8.2 Value Stream Mapping

According to Womack and Jones (2003) the objective of value stream mapping is to identify every action involved in creating a product (or delivering a service) and then splitting each of these actions into one of three categories:

1. Those which create value to the customer
2. Those which create no value, but cannot be eliminated yet
3. Those which do not create value for the customer and can be immediately eliminated

The main process in lean value stream mapping (VSM) is to begin with a current state value stream map, assess that current state, and then develop a future state map where the issues with the current state map are rectified. Figure 3.16 shows the general concept of VSM, which is to move from the current state to the future state and use a variety of lean metrics and improvement measures.

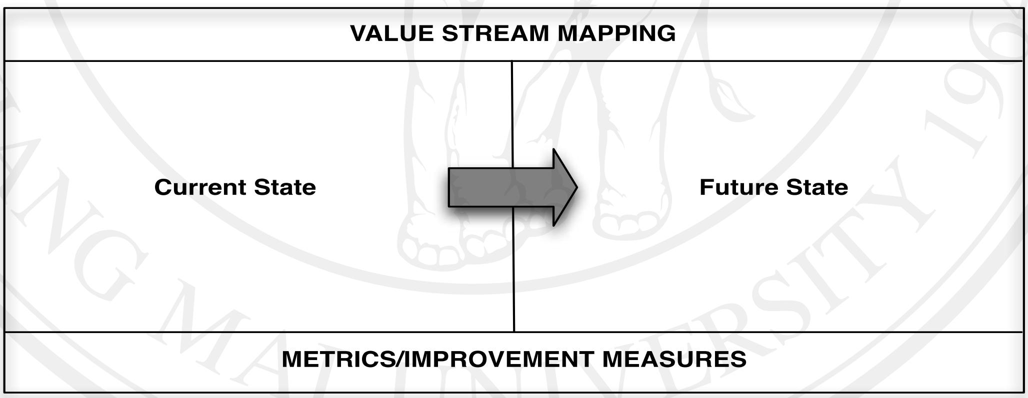

Figure 3.16 The concept and method behind value stream mapping, whereby a current state is mapped before creating a future state and the associated metrics and improvement methods to achieve that future state

Based on the decision matrix in the select phase of the research, three key safety process areas were selected for lean VSM. The reason for choosing three areas of focus was for a number of reasons. Firstly, the initial implementation of lean requires sufficient management support, and must be an area worthy of attention, so that everyone in the organization supports the application of lean (Liker, 2004). In short, the selected processes for lean application must be important enough to capture organizational attention. This is the justification for the decision matrix and UML activity diagrams in the select phase, which were used to identify and select the three

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most appropriate processes for a lean thinking focus. The other reason for selecting three processes for lean focus is that the philosophy behind lean thinking is that processes should be selected, and improved in a carefully considered and manageable way before moving onto other processes (Womack and Jones, 1992). School management felt three areas was the right number for the initial focus. Three key processes were therefore selected for application of lean and VSM. These were:

1. Responding to the needs and suggestions of parents
2. Safety budgeting and planning
3. Safety compliance

Two VSMs were applied to each of these processes, the current state VSM, and the future state VSM, thus in total, six VSMs were created. The application of VSM followed the methodology proposed by Womack and Jones (1992), and modified by Keyte and Locher (2004). Completing the current state VSM for each of the three activities consisted of four steps. These are listed below and subsequently described in more detail:

1. Identify the main processes for the activity and in the correct order
2. Perform a value stream walkthrough and fill in process metrics
3. Calculate individual process metrics
4. Identify value added and non-value added tasks and calculate summary metrics for the entire current state VSM

1. Identify the main processes for the activity and in the correct order:

This step set about discovering the current processes in a particular activity and the order in which they took place. For example, for the UML activity diagram related to responding to the needs and suggestions of parents, the main processes for this were identified. These processes were then sketched out in the correct order. The identification of the main processes took place with school management including the school director, manager and two safety managers.

2. Perform a value stream walkthrough and fill in process metrics:

This step of the current state VSM consisted of walking through the processes identified in step one. The walkthrough had a dual purpose; firstly it enabled a check to ensure all the main processes had been covered, and secondly, it enabled process metrics to be completed. Process metrics were collected by interviewing the people involved in each of the processes. The main process metrics collected are shown in Table 3.4.

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Table 3.4 The process metrics collected during VSM and the rationale behind the collection of these metrics

Process Metric Collected	Details	Rationale
Process time (P/T)	The amount of time required to finish a process.	Each process within a VSM takes a particular amount of processing time to complete, and when completing the current state VSM, there was a need to understand how time-intensive each process was, so that they could be improved in the future state VSM.
Lead time (L/T)	The latency between the start of a process and its completion (i.e. the total time a process takes including work delays).	While a process might only take a small amount of processing time to complete, other aspects might delay the overall process. The lead-time is therefore a measure of how long a process takes to complete, including all the delays and wait times a process might endure.
Difficulty	Difficulty of a process on a scale from 1-5. Difficulty was measured both for new staff having to complete the task and existing staff.	Each process has an associated difficulty, and must be measured to see whether these processes can be made easier. The processes were measured in terms of how difficult they were for existing personnel versus newly employed personnel.

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Table 3.4 The process metrics collected during VSM and the rationale behind the collection of these metrics(Continue)

Process Metric Collected	Details	Rationale
No. of trained personnel	The number of personnel trained to complete a particular process out of the total number of personnel who are involved in the process.	It was important to know how many personnel were trained to undertake a particular process compared to the total number of personnel involved in that particular process.

4. **Calculate Individual Process Metrics:**

Once the processes had been mapped in the correct order, and the associated process metrics had been collected, the next step was to carefully calculate and note the process measures for each step in the current state VSM. Figure 3.17 shows the syntax used in the VSM diagrams and for the process metrics.

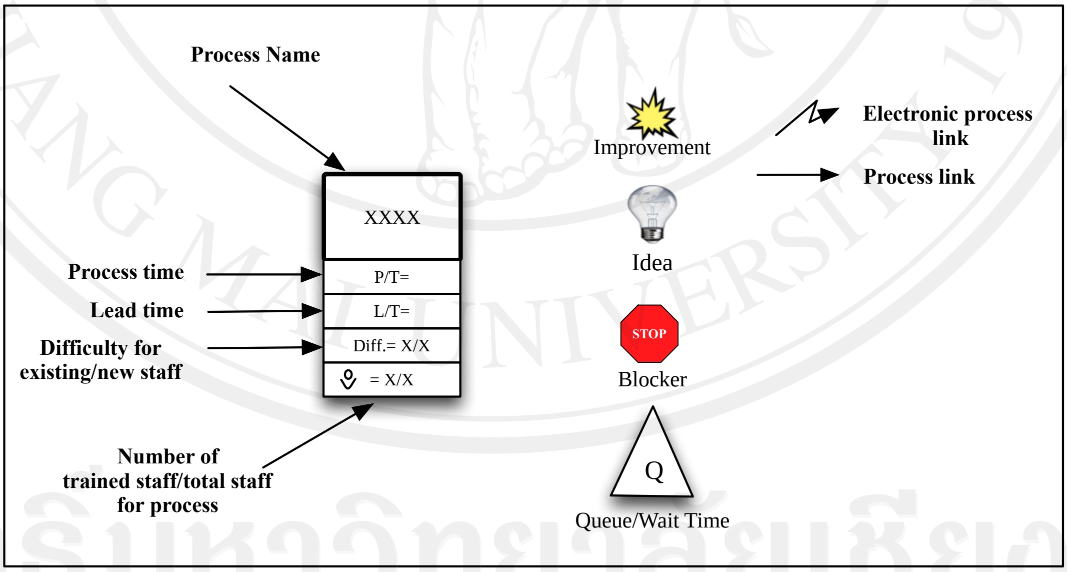

Figure 3.17 The syntax/symbols used in the value stream mapping (VSM)

5. **Calculate summary metrics for the entire current state VSM:**

Once the individual processes had been mapped out and the process metrics collected, the next step involved calculating summary metrics for the entire

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current state VSM. This included the total number of steps in the VSM, the total processing time, and the total lead-time. Each process in the current state VSM was also assessed to determine whether it was a value adding, or non-value adding step. This then allowed a calculation of the total percentage of value added steps and value added time in the current state VSM.

After the three current state VSMs were completed and the associated metrics were calculated, the next step involved design of the future state VSMs in order to enhance the chosen safety processes at the school by reducing waste, cutting non-value adding steps and reengineering the current processes. One of the key ways in which the current state VSMs were improved for future lean change, was via the application of the seven wastes tool.

3.8.3 Developing the Future State Value Stream Maps

After creation of the current state value stream maps, a variety of lean tools were applied to improve these and create future state value stream maps, which could then be implemented at the school to improve safety related processes. The main tools to improve the current state maps and create the future state maps were the seven lean wastes (muda), mura (unevenness), and muri (overburden) as well as the 5S tool. These are each described in turn with reference to how they were applied to create the future value stream maps.

3.8.4 Seven Wastes (Muda)

Muda is any activity which doesn’t add value to a process, and is thus considered a waste. Muda can be separated into seven types of waste, and together, these seven wastes form Muda, which originated in Japan. The seven types of waste are shown below in Figure 3.18.

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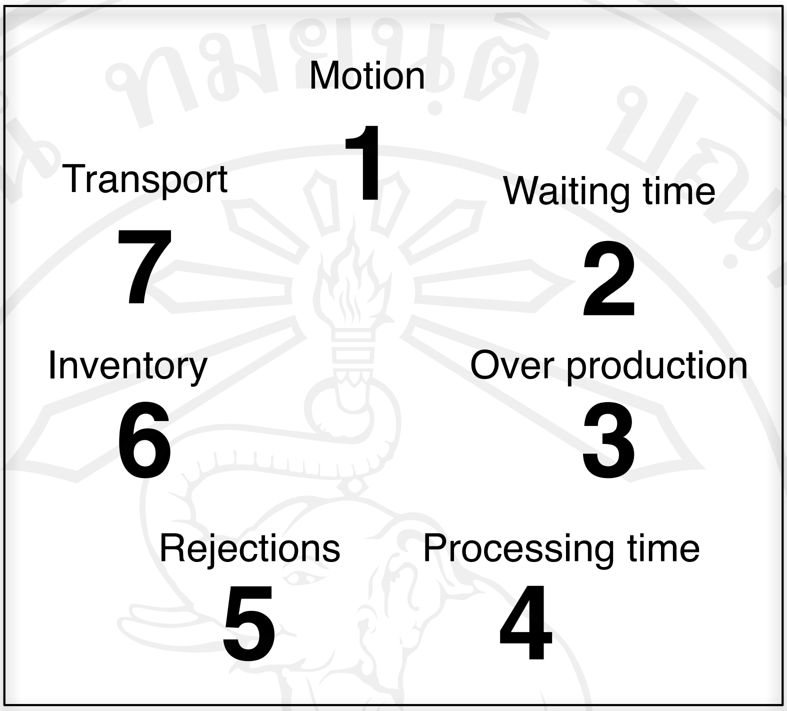

Figure 3.18 The seven wastes, which together form Muda (adapted from Hallihan et al., 1997)

The seven wastes now forms part of the lean thinking toolbox, and has been used by a variety of practitioners and academics when applying lean, and developing value stream maps (e.g. Radnor et al., 2012; Villarreal, 2012). The seven types of waste shown in Figure 3.16 were originally documented by Womack et al. (1990), with particular reference to the Japanese car manufacturing industry, but have since been adapted to service and office processes (e.g. Apte and Goh, 2004; Kim et al., 2006; Jones et al., 1999; Main et al., 2008). In this work, the seven wastes were adapted to the various wastes associated with the school safety processes, and Table 3.5 shows examples of the seven wastes as they relate to school safety processes, and service sector examples more generally.

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Table 3.5 The seven wastes and corresponding examples related to school safety

Seven Types of Waste	Examples from School Safety
1. Motion (human movement)	Many steps associated with safety in the school and significant movement around the school to ensure safety.
2. Waiting time	Waiting for approval or for information about safety related processes. Downtime of office equipment related to safety such as computers/telephones.
3. Overproduction	Too many safety related suggestions and comments from parents making school safety difficult to manage effectively.
4. Processing time/overprocessing	Too much processing, too many steps, and multiple information systems for the same task.
5. Rejections	Errors in communication or data entry related to school safety.
6. Inventory	Purchasing or doing safety related tasks when they are not necessary. For example, implementing a safety suggestion that is unnecessary or not needed.
7. Transport	Excessive movement of paperwork, emails and other items related to safety in the school.

The seven wastes shown in Figure 3.16 and Table 3.5 were used to assess each of the three lean value stream maps at the school. The value stream maps were systematically assessed with a group of school stakeholders in order to identify key areas for improvement and significant areas of waste, which could be reduced during the development of the future state value stream maps. There were four main groups involved in the assessment of the current state value stream maps. These groups and the justification for their involvement are described below:

1. **School director** – the school director acted as the leader of the VSM improvement via the seven wastes. The director has an overview of all school processes and is responsible for all aspects of safety in the school.
2. **School manager and selection of administrative staff** – the school manager also has responsibility for safety, and along with the administrative staff has a good understanding of safety processes and the financial aspects involved.

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3. **School safety managers** – the two school safety managers have a responsibility for safety in the school and are aware of all safety related processes and how they might be changed/adapted.
4. **Selection of teachers involved in safety processes** – a random selection of five school teachers were selected to assist in the identification of the seven wastes. The school's teachers have an important perspective of how the safety processes work in practice, and provided a useful perspective from which to identify and reduce some of the seven types of waste.

As well as the seven wastes (muda), the other lean aspects of mura (unevenness) and muri (overburden) were considered when designing the future value stream maps. Mura and muri are often termed the forgotten Ms, as they form an important part of lean thinking, but are often overshadowed by muda. Following muda, mura and muri in sequence, is noted as the most logical improvement method in lean thinking (Womack and Jones, 2003). Figure 3.19 illustrates the progression of muda, mura and muri.

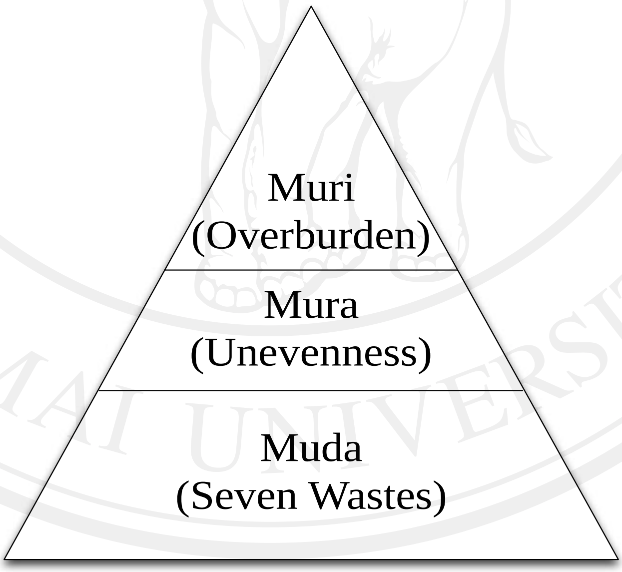

Figure 3.19 The three MUs in lean (muda, mura, muri)

3.8.5 Mura and Muri

Mura is the Japanese word for unevenness in any operation or process, while muri is defined as overburden (Womack et al., 1990). After assessing the current value stream maps in relation to the seven wastes, mura and muri were also considered. As with all the applications of lean in this

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research, the focus was on adapting the concepts to the school, and in particular the safety processes within the school. Mura and muri were combined in synergy with muda, to create lean improvement to the value stream maps of safety processes at the school. Figure 3.20 shows this combination of the three aspects of muda, mura, and muri.

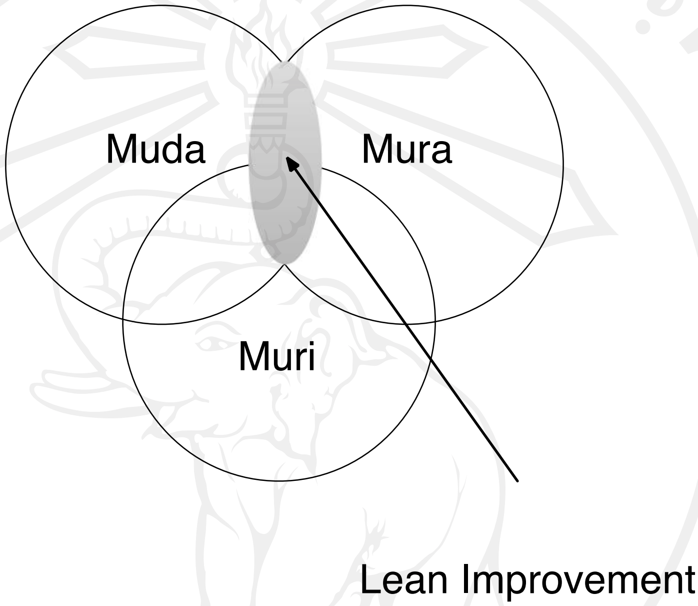

Figure 3.20 The three components of muda, mura, and muri, which are applied together to create lean improvement

The final aspect in achieving lean improvement in relation to the school safety processes was application of the 5S tool.

3.8.6 Application of 5S

5S is part of the lean thinking framework of tools, and represents sort, set, shine, standardize and sustain, which originated from the Japanese words Seiri (Sorting), Seiton (Setting), Seiso (Shining), Seiketsu (Standardizing) and Shitsuke (Sustaining). The first three Ss are mainly used for managing objects and places, while the forth and fifth Ss are used for managing people. The aim of the 5S tool is eliminating wastes and improving product or service quality to meet customers' satisfaction. In essence, the 5S is a housekeeping methodology to improve work and the associated processes (Michalska et al, 2007). 5S has been shown to be effective when used alone, but even more so when combined with other aspects of lean, and acts as a

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standardizing method (Waldhausen et al., 2010). The 5Ss are described below:

1. **Sort** – This is the first of the 5Ss and involves sorting the workplace or processes to remove unnecessary items.
2. **Set** – This is the second of the 5Ss and is related to ensuring the workplace is effectively organised.
3. **Shine** - The third of the 5Ss, this ensures the workplace is clean and streamlined to ensure any unnecessary clutter can be removed.
4. **Standardise** – The fourth aspect of the 5Ss is to ensure any work or process is performed in a standard way using the same guidelines when doing work.
5. **Sustain** – The fifth and final of the 5Ss aims to ensure that the 5S methodology and improvements are sustained.

The main way in which 5S was applied in this research is via the development of a decision support model to assess safety suggestions from parents and staff in the school.

The current safety suggestion system is a process which requires significant amounts of time and management, and therefore, in combination with the value stream mapping, the 5S tool was applied to the process of managing school safety suggestions.

3.8.7 Using 5S for a Safety Suggestion Decision Support Model

To improve school safety, the school needs to collect suggestions from parents' perspectives, however there are considerable difficulties for schools when selecting and applying appropriate suggestions. Thus a decision support method was developed with the 5S methodology in mind in order to improve the processes associated with managing and deciding whether to implement safety suggestions.

A decision support system developed in isolation from other aspects of school safety would not be in keeping with the lean methodology and would not be effective in improving school safety unless other aspects of the school's safety infrastructure were in place. Table 3.6 shows how each of the 5S steps is related to the creation of the decision support model. The actual design and implementation of the decision support model is explained below in section 3.8.8.

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Table 3.6 The relationship between the 5S methodology and the creation of a safety suggestion decision support system

5S Steps	Relationship to the Decision Support System
1. Sort	The decision support model provides a way to sort each safety suggestion from those which are feasible and should be implemented, to those which should not.
2. Set	The current procedure for school safety suggestions is not explicitly detailed and safety suggestions are currently addressed in an *ad hoc* and random way. The decision support model will allow a set procedure to be establishing and an order to be followed when dealing with safety related suggestions.
3. Shine	By following the decision support model when dealing with safety suggestions, any unnecessary processes can be removed and in alignment with the value stream mapping, the safety suggestions can be dealt with in an efficient and effective way.
4. Standardize	The current method of dealing with safety suggestions is variable, and dependent on a number of factors. The decision support model will ensure a standardized approach to dealing with school safety suggestions.
5. Sustain	By using the decision support system, it will be easy to sustain the previous 4Ss and ensure that school safety suggestions are always addressed in the same way, and in alignment with principles of lean thinking.

Creating the decision support system was a complex and multifaceted step of the research, and was undertaken via the analytic hierarchy process, which is detailed in the sections below.

3.8.8 The Analytic Hierarchy Process (AHP)

The analytic hierarchy process (AHP) was used to create a systematic and standardized way of approaching decisions related to safety suggestions in the case study school. The current approach to safety-related decisions is ad-hoc and variable based on a number of factors, such as who reports the suggestion, how the suggestion is discussed, when the suggestion is discussed, and the degree to which the suggestion is scrutinized by decision makers. In short, the current approach to making decisions regarding safety-related suggestions is highly variable, and unpredictable. The use of AHP was to reduce this variability and provide a universal approach to analyzing

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safety related suggestions in the school. To apply AHP to school safety suggestions was a complex process, which built an AHP model and user interface using Microsoft Excel.

The analytic hierarchy process (AHP) is a form of multiple criteria decision making. AHP uses a hierarchical approach to structure and analyse complex information to make a decision, and is widely used in management science to establish priorities when dealing with multicriteria problems (Bernasconi et al., 2010). It is suggested that AHP can help decision makers facing complex issues, with multiple conflicting and subjective criteria (Alessio et al., 2009). In this research, AHP was used to sort and standardize the decision making process associated with safety related suggestions given to the school by parents. The AHP model links to lean by attempting to improve the processes associated with safety suggestions, and fits the 5S methodology in terms of sorting safety suggestions and standardizing the process used to make decisions.

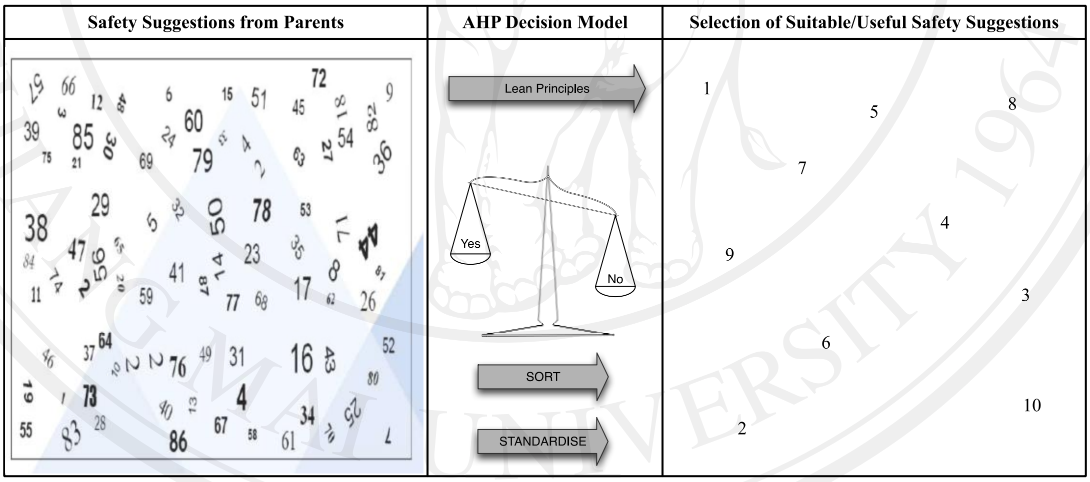

Figure 3.21 The AHP principle and its relationship with the lean knowledge management philosophy of this research

According to Illangasekare et al. (2007), a carefully considered problem structure is key to successful multiple criteria decision making, and thus a successful implementation of AHP must also begin with a carefully considered problem structuring process.

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3.8.8.1 Problem structuring (problem ontology) and Decision Criteria: Creating the Hierarchy

Hierarchies enable complex problems to be broken down into smaller pieces for analysis. The principle of AHP relies on this hierarchical approach to problems, and therefore, the first step in creating the hierarchy was to develop an ontology based on the key criteria required to make a decision on the feasibility of a safety-related decision. After discussion with school management, three main aspects were considered critical when making a decision regarding the feasibility of safety suggestion. These aspects, along with a brief description are explained below.

1. **Budget** – this was discussed as being one of the most important aspects for a private school when considering a safety suggestion from parents. Cost can quickly make a suitable safety suggestion prohibitive, and the balancing of safety related costs versus other school costs is challenging for school management. For example, the opportunity cost of spending on the implementation of a safety suggestion could lead to a reduction in academic quality, which is ranked by parents as equally or more important than school safety.
2. **Safety Impact** – As well as budget, the impact the safety suggestion has upon the school is considered important. Safety suggestions should be considered in terms of how they would affect safety and the potential impact they have upon risk and accident reduction.
3. **School Impact** – The overall impact on the school is also important. This refers to the wider impact the suggestion could have on the school. For example, as well as the intrinsic impact on safety, a suggestion could also affect the appearance of the school, or the workload of staff.

These three aspects were then broken down into further sub-criteria, so that the full decision making process could be mapped and carefully considered. The sub-criteria were determined as follows:

Budget sub-criteria – in terms of budget, there were two main sub-criteria, the initial cost of implementing the safety suggestion, and the maintenance cost associated with keeping the safety suggestion in place. For example, initial cost might refer to the initial fixed cost associated with implementing a particular safety suggestion, while maintenance cost would be the variable costs associated with keeping a safety suggestion in place.

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Safety impact sub-criteria – for safety impact, three main sub-criteria were considered important when assessing safety suggestions. These were accident reduction, risk reduction, and safety perception. Accident reduction relates to whether the safety suggestion will have any impact on the cessation of accidents in the school. While being similar, risk reduction is subtly different from accident reduction, and refers to how risk in the school might be reduced (for more details on the differences between accidents and risk as they pertain to school safety, see Chapter 2, section 2.4). Safety perception relates to how the suggestion would affect the overall feeling and perception of safety within the school. For example, whether implementing a suggestion would lead to an increased feeling of safety in the school and how parents, teachers, staff and students would perceive the safety suggestion if it was implemented.

School impact sub-criteria – The school impact sub-criteria relate to the effect a safety suggestion might have on various aspects of the school. The school impact sub-criteria were split up and further separated according to invitational theory. As described in Chapter 2 (section 2.6), invitational theory separates the school into five key areas: people, places, policies, programs and processes. Thus the school impact sub-criteria were further separated according to these five categories. The five invitational theory categories were then divided where appropriate to ensure all criteria were adequately addressed in the AHP decision model. Table 3.7 illustrates the five invitational theory categories and how they were further separated to take into account the potential impact of a safety suggestion on the school.

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Table 3.7 The school impact sub-criteria derived from the five invitational theory categories

Invitational Theory Aspect	**Further Divisions**	**Justification**
People	• Workload • Parental Perception • Parental cooperation (distinct from safety perception above, as this refers specifically to parental perception)	'People' is a broad category from which to assess the impact of a safety suggestion. Thus this was further separated into how people might be affected in the school. Specifically, whether there will be an increase in workload, whether parents will be required to cooperate with the school and finally, whether parents will be affected in terms of their perception of safety and the school.
Place	• Building • Playground • School drop-off	Like the 'people' category, 'place' is difficult to assess as a whole and was separated into the key areas in the school (particularly those affected by safety).
Policies	• National School Act • Private School Act	School policies are affected by legislation through two main Acts: these formed the sub-criteria related to school policies and how they would be affected by or impact a school safety suggestion.
Programs	• Not separated further	This category was distinct enough that it did not require further sub-criteria.
Processes	• Not separated further	This category was distinct enough that it did not require further sub-criteria.

After consideration of the multi criteria problem of school safety suggestions, 15 root criteria were defined. Together these 15 root criteria feed the overall decision criteria of budget, safety impact, and school impact.

1. Initial cost

2. Maintenance cost

3. Accident reduction

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4. Risk reduction
5. Safety perception
6. Workload
7. Parental perception
8. Parental cooperation
9. Buildings
10. Playground
11. School drop-off
12. National School Act
13. Private School Act
14. Programs
15. Processes

Together these decision criteria form an ontology, which represents the problem structure when deciding whether or not to implement a safety suggestion at school. Figure 3.22 visually illustrates this ontology.

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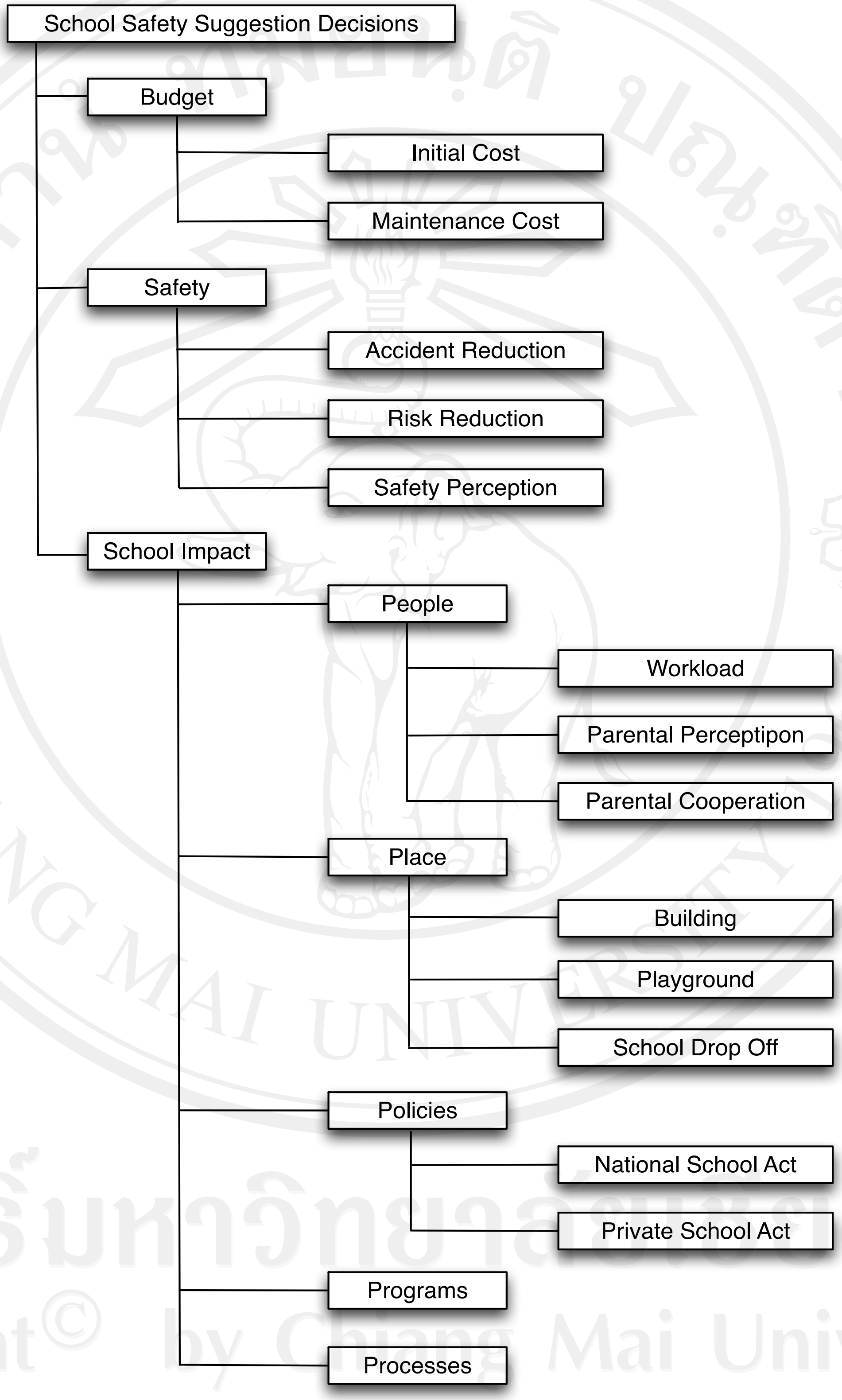

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Figure 3.22 The safety suggestion decision criteria ontology for creation of the AHP

3.8.8.2 Pairwise Comparison and Quantitative Criteria Evaluation

The second step of the AHP decision model involved pairwise comparisons of the potential factors affecting the decisions. According to Triantaphyllou and Mann (1995) a crucial step in decision-making is the estimation of important data, but with qualitative data (such as data about school safety) it is difficult to know in absolute terms. In decision-making, this results in the need to understand the relative importance of each possible alternative when making a decision. In the AHP methodology, this relative weighting of criteria is determined using the process of pairwise comparisons. Pairwise comparisons are undertaken through a procedure of rating decision criteria against each other using linguistic statements, such as “A is more important than B” and then determining the level of importance using a scale such as the one proposed by Saaty (1980) and shown in Table 3.8.

Table 3.8 Scale of relative importance during pairwise comparisons (derived from Saaty, 1980)

Value	Definition (importance of one criteria over another)	Explanation
1	Equal importance	Two criteria contribute equally
2	Weak or slight importance	One criteria is slightly favoured over the other
3	Moderate importance	
4	Moderate plus importance	One criteria is strongly favoured over another
5	Strong importance	
6	Strong plus importance	One criteria is very strongly favoured over another and is demonstrated in existing practice
7	Very strong or demonstrated importance	
8	Very, very strong importance	One criteria is favoured over another at the highest possible level
9	Extreme importance	

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Table 3.8 Scale of relative importance during pairwise comparisons (derived from Saaty, 1980) (Continue)

Value	**Definition (importance of one criteria over another)**	**Explanation**
Reciprocals of above numbers	If a criteria (i) has one of the above numbers assigned to it when compared to activity j, then j has the reciprocal value when compared with i	

The pairwise comparisons can be built up to assess the relative importance of one factor over another for a variety of criteria. Figure 3.23 illustrates a simplified example of a pairwise comparison using the example of the possible choice presented when buying a car. The three decision criteria of safety, speed, and fuel economy are compared against each other in a series of pairwise comparisons and then given a rating based on how much more important one criteria is versus another.

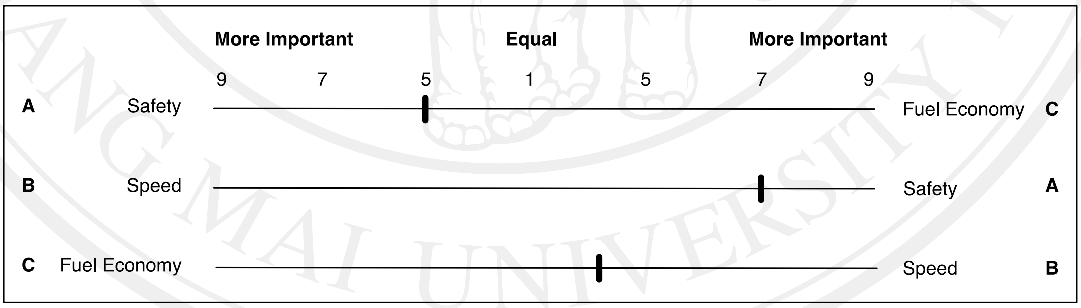

Figure 3.23 A simplified example of a pairwise comparison conducted when making a decision on buying a car

After the pairwise comparison, the data is placed into a matrix to begin to evaluate the criteria in terms of their importance and to ultimately ascribe a weighting to these criteria. An example decision matrix based on the previous example of deciding on the purchase of a car is shown in Table 3.9 along with the pairwise comparison scores and the reciprocals.

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Table 3.9 Example decision matrix based on pairwise criteria
with appropriate values and reciprocals

Car Choice	**A (Safety)**	**B (Speed)**	**C (Fuel economy)**
A (Safety)	1	7	5
B (Speed)	1/7	1	3
C (Fuel economy)	1/5	1/3	1

Once the pairwise matrix is completed, any reciprocals are converted to decimal numbers, and the columns are then totaled. Each number in the matrix is then divided by the appropriate column total, to produce a normalized matrix. An example is given for the AHP created in this thesis using the safety impact criteria of accident reduction, risk reduction and safety perception, which is taken from the AHP ontology shown in Figure 3.22 Table 3.10 illustrates the decision matrix created for these criteria, along with the reciprocals and conversion to decimals where appropriate.

Table 3.10 An example of one of the decision matrices created for
the safety impact criteria, derived from the ontology presented in Figure 3.22

Criteria	**A** (Accident Reduction)	**B** (Risk Reduction)	**C** (Safety Perception)
A (Accident Reduction)	1	2	7
B (Risk Reduction)	1/2 (0.5)	1	3
C (Safety Perception)	1/7 (0.14)	1/3 (0.33)	1
Totals	1.64	3.33	11

Once the matrix had been completed, it was normalized by dividing each number by its column total. This then resulted in a normalized decision matrix, as exemplified in Table 3.11.

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Table 3.11 The normalized decision matrix created for the safety impact criteria

Criteria	**A** (Accident Reduction)	**B** (Risk Reduction)	**C** (Safety Perception)	**Row Average (Criteria weighting)**
A (Accident Reduction)	0.61	0.60	0.64	0.62
B (Risk Reduction)	0.30	0.30	0.27	0.29
C (Safety Perception)	0.09	0.10	0.09	0.09

The row average in the normalized decision matrix provides an overall weighting for each of the three criteria. In the example shown in Table 3.11, accident reduction has the highest weighting at 0.62, followed by risk reduction at 0.29 and finally, safety perception at 0.09. Seven matrices were built, representing the whole safety ontology, and were then combined to form a complete AHP model to use when assessing school safety suggestions. However, before these matrices could be combined, there was a need to assess consistency in the pairwise comparisons to ensure the weighting of the various safety criteria was consistent. This is recommended by Saaty (1980) and all other literature utilizing AHP as a decision making model (e.g. Karapetrovic and Rosenbloom, 1999; Barzilai, 1998; Finan and Hurley, 1997).

3.8.8.3 Measuring AHP Consistency: The Consistency Index

To calculate the consistency ratio required a series of four steps. Together these led to the creation of a consistency ratio (CR) for each of the matrices constructed for the AHP model. To compute the CR, the following four steps were undertaken:

1. Calculation of the **weighted sum vector**
2. Calculation of the **consistency vector**
3. Calculation of the **consistency index (CI)** and **lambda**
4. Computation of the **consistency ratio (CR)**

To complete the first step and calculate the weighted sum vector, the first criteria weighting from the normalized decision matrix was multiplied by each of the values in the first column of the original pairwise matrix. The

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second criteria weighting was then multiplied by each of the values in the second column of the original pairwise matrix and finally, the third criteria weighting was multiplied by each of the values in the third column of the original pairwise matrix. These values were then summed across the rows. Equation 3.1 illustrates this process.

Criteria weightings:
1st (Accident reduction) = 0.62
2nd (Risk reduction) = 0.29
3rd (Safety Perception) = 0.09

$$\begin{pmatrix} (0.62) * (1) + (0.29) * 2 + (0.09) * (7) \\ (0.62) * (0.5) + (0.29) * (1) + (0.09) * (3) \\ (0.62) * (0.14) \ + (0.29) * (0.33) + (0.09 * (1) \end{pmatrix} = \begin{pmatrix} 1.848 \\ 0.877 \\ 0.277 \end{pmatrix}$$

Equation 3.1 An example of the **weighted sum vector** calculation

Following calculation of the weighted sum vector calculation, the consistency vector was calculated by simply dividing each of the weighted vector sum calculation results from Equation 3.1 (above) by the original criteria weightings. This step is illustrated in Equation 3.2.

$$\begin{pmatrix} (1.848)/(0.62) \\ (0.877)/(0.29) \\ (0.277)/(0.09) \end{pmatrix} = \begin{pmatrix} 3.0049 \\ 3.0022 \\ 3.0007 \end{pmatrix}$$

Equation 3.2 Calculating the **consistency vector** using the results from Equation 3.1 and the original criteria weightings from the decision matrix.

Once the consistency vector has been calculated, the consistency index and lambda can be derived. Lambda is simply defined as the mean value of the consistency vector. The consistency index (CI) can then be calculated using Equation 3.3.

$$CI = \frac{\lambda - n}{n - 1}$$

Equation 3.3 Calculating the **consistency index (CI)**, where *n* is the number of decision criteria being compared (in this example, *n* = 3)

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In the case of the example presented, the CI is calculated as shown in Equation 3.4.

$$Lambda\ (\lambda) = \frac{3.0049+3.0022+3.0007}{3} = \underline{\underline{3.002}}$$

$$CI = \frac{3.002-3}{3-1} = \underline{\underline{0.0013}}$$

Equation 3.4 Calculation of the **Consistency Index (CI)** for the example criteria presented

After calculating the CI, the final step is the computation of the consistency ratio (CR). This is simply the CI (as shown in Equation 3.4) divided by the random index (RI). The RI is provided by the literature from the original architect of the AHP process (Satty, 1977) and is shown in Table 3.12.

Table 3.12 Random Consistency Index (RI) (adapted from Saaty, 1977)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The CR in was then calculated according to the example of safety impact criteria, which is shown below in Equation 3.5.

$$CR = \frac{CI}{RI}$$

$$CR = \frac{0.0013}{0.58} = \underline{0.0022\ (0.22)}$$

Equation 3.5 Calculation of the **Consistency Ratio (CR)**

The consistency ratio serves to illustrate how consistent the pairwise comparisons have been for each matrix and thus acts to ensure consistency and reliability in the resulting model. The general rule is that the CR should be below a value of 0.10 (10%). In this example, the answer is below this number and thus it can be surmised that the pairwise comparisons have been consistently and appropriately structured and valued. If the consistency value was above 0.10, then the pairwise comparisons were revisited to ensure

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consistency in the final AHP model. Seven matrices were computed in the final AHP model in this work, and the consistency was checked for each matrix. Once these matrices had been completed, they could be aggregated according to the ontology shown in Figure 3.22 to create the final AHP model and structure. After aggregation, calculations were performed to link each matrix in the model and create an overall decision support model for the school safety suggestions, which calculated a single score based on user input and was calculated from the various weighted criteria in the AHP model.

3.8.8.4 Criteria Aggregation and Final Hierarchy

After pairwise comparison of all the appropriate criteria, and the consistency analysis to ensure consistent analysis of these pairs, the criteria were aggregated to form the final hierarchy in the model. This hierarchy consists of five levels, and is shown in Figure 3.24.

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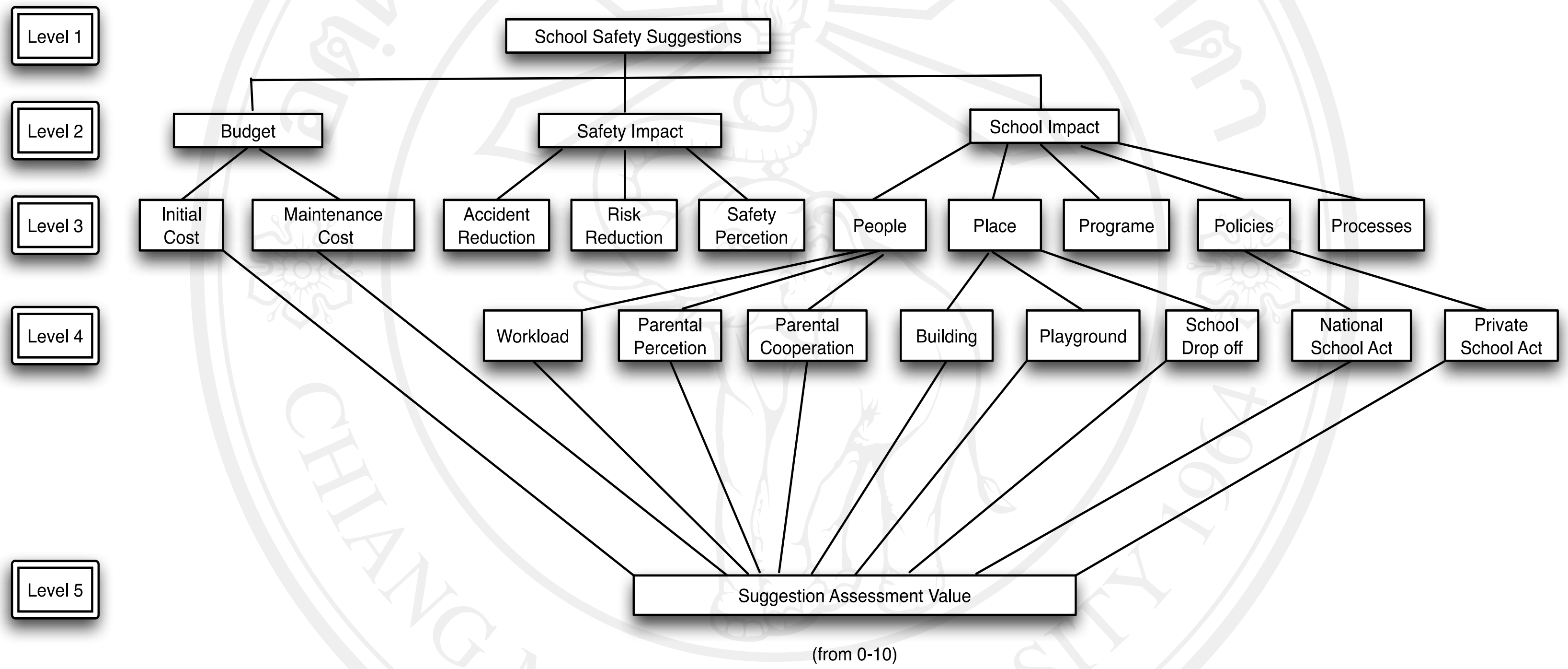

Figure 3.24 The final AHP hierarchy and five corresponding leve

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3.8.8.5 Weighted Sub Factors and Hierarchy Concatenation

The seven pairwise comparisons undertaken to complete the AHP model are as follows:

1. Pairwise comparison of budget, safety impact and school impact – three factors compared representing level two of the AHP hierarchy.
2. Pairwise comparison of initial cost and maintenance cost, representing the sub factors related to the budget category – two factors compared representing level three of the AHP hierarchy.
3. Pairwise comparison of accident reduction, risk reduction and safety perception, representing the sub factors related to the safety impact category – three factors compared representing level three of the hierarchy.
4. Pairwise comparison of people, place programs, polices and processes, representing the sub factors related to the school impact category – five factors compared (5Ps of invitational theory) representing level three in the hierarchy.
5. Pairwise comparison of workload, parental perception and parental cooperation, representing the sub factors related to the people category – three factors compared representing level four in the hierarchy.
6. Pairwise comparison of buildings, playground and school drop-off area, representing the sub factors related to the place category – three factors compared representing level four in the hierarchy.
7. Pairwise comparison of National School Act and Private School Act, representing the sub factors related to the policies category – two factors compared representing level four in the hierarchy.

After completing these seven pairwise comparisons and associated consistency tests, the appropriate weighting of each sub factor was computed in relation to the overall hierarchy. This was calculated according to Equation 3.6.

$$Sub\ factor\ weight\ (SWij) = Wi * (Vij)$$

Where:
Wi = main factor weight (*i*)
Vij = Weight of sub factor (*j*) within the factor (*i*)
Equation 3.6 Calculating the **sub factor weights** within the AHP model

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Each sub-factor in the hierarchy thus has its own local weighting (according to the pairwise comparisons) and a global weight in the model, which was based on Equation 3.6 and allowed each sub factor to be linked with its main factor weighting. The local and global weightings for each factor and sub factor are illustrated in Table 3.13 and graphically on the AHP in Figure 3.25.

Table 3.13 The local and global weightings of the main factors and sub factors in the AHP safety suggestion model

Main Factors	Sub factors		Local Weighting	Global Weighting
Budget			0.48	n/a
	Initial cost		0.75	0.35
	Maintenance Cost		0.25	0.11
Safety impact			0.35	n/a
	Accident reduction		0.62	0.21
	Risk reduction		0.29	0.10
	Safety perception		0.09	0.03
School impact			0.17	n/a
	People		0.59	0.102
		Workload	0.61	0.062
		Parental perception	0.30	0.030
		Parental cooperation	0.09	0.009
	Place		0.19	0.032
		Buildings	0.21	0.007
		Playground	0.08	0.002
		School drop-off	0.071	0.023
	Programs		0.08	0.014
	Policies		0.04	0.007
		National School Act	0.75	0.005
		Private School Act	0.25	0.001
	Processes		0.09	0.015

The weightings shown in Table 3.13 are illustrated graphically on the AHP structure in Figure 3.25.

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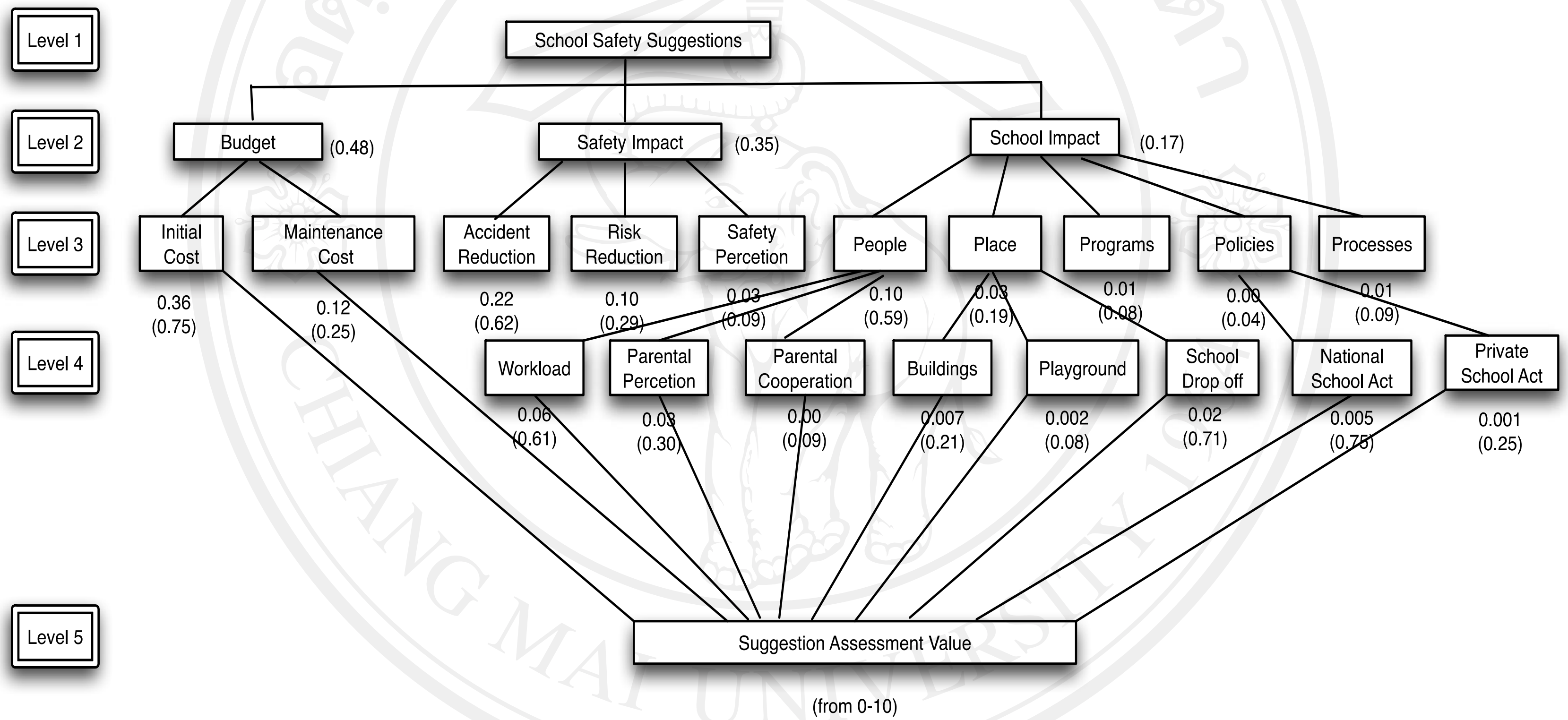

Figure 3.25 The Final AHP model complete with local weightings from the pairwise comparisons (shown in parentheses) and global weightings used within the whole AHP to calculate the final suggestion assessment value

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The final model was then constructed so that users were required to grade the 13 sub factors from a scale of 1-10. This input was then combined with the weighting via a calculation which multiplied the values of the scale given by the user with the weighting of the particular sub-factor. Thirteen criteria were given a score from 1 to 10 by the user, each of which was multiplied by the appropriate sub factor weighting in Table 3.13 and Figure 3.25 before being combined to create the final suggestion assessment score. For some of the user input scores, where a high value indicated a negative impact on the feasibility of the suggestion (e.g. high initial cost), mathematical manipulation inside the model allowed for an inverse of the score to be computed prior to summation for calculation of the final suggestion assessment value.

3.8.8.6 Reducing Complexity for User Input: Building a Microsoft Excel Model

The complex AHP model calculations were built into a Microsoft Excel model, which also allowed a simple user interface to be created. This user interface enabled staff, teachers and management to use the AHP model in a simple and straightforward way, while the complexity of the AHP model remained hidden. The user interface was created in both Thai and English, and comprises a simple drop-down list with categories for users to choose from when rating a safety suggestion. This enables a fast and simple decision to be made regarding a safety suggestion, while ensuring that each aspect is considered in a standardized way by utilizing the power of the AHP decision-making capability. Figure 3.26 illustrated an example screenshot of the final AHP input screen for teachers, staff and students.

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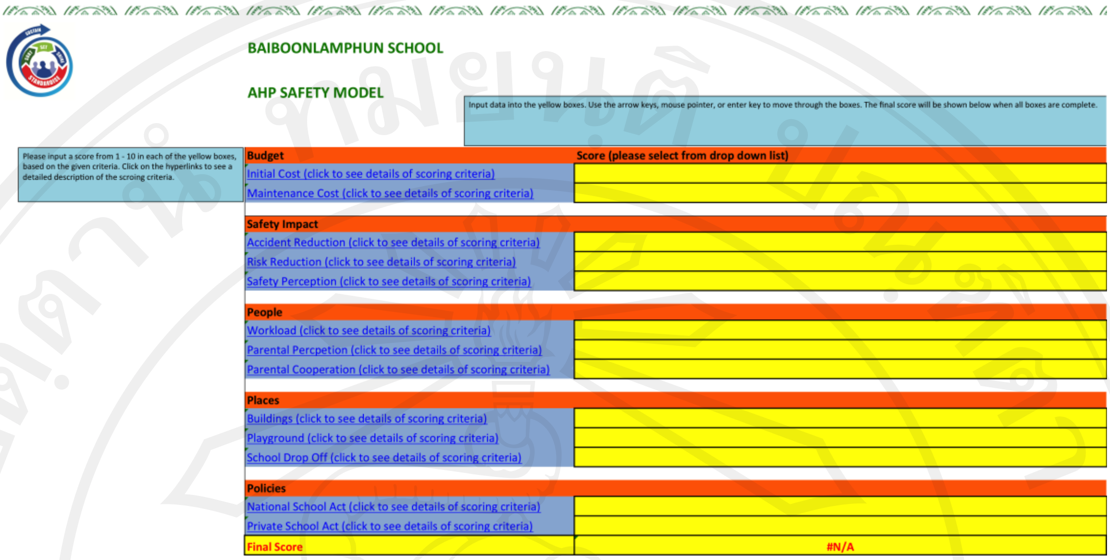

Figure 3.26 Screenshot of the AHP safety suggestion input screen

The AHP model gives the user an output (suggestion assessment value), which is a score between 1 and 10. This score is based upon the user input and the weightings in the model. The scores allow suggestions to be sorted, and those which achieve a high enough model score (above 4.0) are further analyzed by the school management team with a view to implementation of the suggestions. Deciding the cut off point as well as how to interpret the suggestion scores was based on a scale created from the AHP literature and testing of AHP suggestions model on previous safety suggestions within the school. The final scores for the model output are therefore assessed using the following scale:

1. Suggestion is of little importance/value.
2. Suggestion could be some of value, but this is unlikely.
3. Suggestion might have some moderate value.
4. Suggestion is likely to have a moderate impact on school safety and at an effective cost.
5. Strong safety impact/value likely from suggestion at effective cost.
6. Strong safety impact/value is very likely from suggestion at an effective cost.
7. Very strong safety impact is likely from suggestion at an effective cost.
8. Very strong safety impact at an effective cost is highly likely from suggestion.
9. Extremely strong safety impact is likely from suggestion at an effective cost.
10. Extremely strong safety suggestion with definite impacts and at an effective cost.

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3.8.9 Using the AHP Model to Assess School Safety Suggestions

The AHP model was then implemented and tested using ten previous school safety suggestions. Five school staff were chosen to use the AHP in rating these suggestions. The five staff were as follows:

1. **School Director** – The school director has a responsibility for everything in the school that affects parents, students and teachers. For example, the school director is responsible for all academic issues, student well being and all other school and parental requirements, including governmental compliance and reporting.
2. **School Manager** - The school manager is responsible for all financial issues in the school, and controls finances to ensure the school runs smoothly without any issues. In terms or safety, the school manager discusses school finances and budgeting related to any school safety proposals.
3. **School Safety Manager** – The safety manager deals directly with all parents, teachers and students regarding safety. The safety manager is the first point of contact for any safety related issue. When the safety issue is serious or involves an expense of over 5000 THB, then the safety issue must be discussed with the school manager and director.
4. **School Administrative Assistant** – The administrative assistants work in the school office and deal directly with governmental reports, financial paperwork and often deal with communication to parents regarding school safety suggestions.
5. **School Administrative Assistant** – As above.

These staff used the Microsoft Excel based model to rate the ten suggestions. The final model score was then recorded and compared among the five staff by calculating the coefficient of variation. The coefficient of variation is computed according to equation 3.7, by dividing the standard deviation of the model scores by the mean and then multiplying by 100 so that the final coefficient of variation can be interpreted as a percentage.

$$C_v = \frac{\sigma}{\mu} * 100$$

Equation 3.7 Calculating the **coefficient of variation (C_v)** to assess AHP scoring of school safety suggestions, where σ is the standard deviation and μ is the mean

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This chapter has so far presented the tools applied in the solve phase of the research, to the explicit aspects and processes associated with school safety. The next part of this chapter focuses on detailing the methodological steps associated with the tacit aspects of improving school safety.

3.8.10 Tacit/Enabling Tools

The tacit and enabling factors in the solve phase consisted of two main parts: rapid process improvement workshops (RPIWs) and knowledge sharing training and activities. The RPIWs are now described.

3.8.10.1 Rapid Process Improvement Workshops (RPIWs)

Rapid process improvement workshops (RPIWs) are another feature of lean, and have been utilized in a variety of empirical research and practical applications to improve the people aspects of lean, rather than the processes. In reality, people and process are linked, and the RPIWs act as a way to bring together people to improve the school's safety processes, as well as introducing and training staff on these new processes and approaches to safety. In line with the knowledge management framework of this thesis, the RPIWs were associated with the tacit and embedded or implicit aspects of knowledge related to improving school safety. A series of three RPIWs were held at the case study school. Each RPIW had a specific purpose related to the improvement of school safety. The RPIWs, along with their purpose and timescales are shown in Table 3.14.

Table 3.14 The three RPIWs along with their objectives, timing, the personnel involved and the outputs

RPIW Objectives	Timing	Personnel Involved	Outputs
RPIW One: To develop staff awareness of lean safety and capture their tacit knowledge related to safety processes at the school	One day at beginning of a three month lean safety development and implementation program. Took place at the weekend so staff duties were not disrupted.	All teachers and staff as well as the school director	1. CEDAC 2. Interrelationship digraph

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Table 3.14 The three RPIWs along with their objectives, timing, the personnel involved and the outputs(Continue)

RPIW Objectives	Timing	Personnel Involved	Outputs
RPIW Two: To raise staff awareness of knowledge sharing and assess their knowledge sharing awareness before and after the training.	One day long and took place after one month of the lean development and implementation program.	All teachers and staff as well as the school director	1. Teacher/Staff pre-test relating to knowledge sharing 2. Teacher/Staff post-test relating to knowledge sharing
RPIW Three: To show how leadership and lean are intrinsically linked, and how staff can be empowered to apply lean to the school and its safety processes.	One day, at the end of the three-month lean development and implementation program.	All teachers and staff as well as the school director	1. Teacher/staff pretest related to the school's leadership and lean implementation. 2. Staff posttest relating to the school's leadership and lean implementation.

3.8.10.2 RPIW One: CEDAC and Safety Processes

According to Table 3.14, the first RPIW took place at the beginning of the three-month lean safety development and implementation program. The objective of this workshop was to capture the tacit knowledge staff possess in relation to the school's safety processes and make this knowledge explicit so that it can be applied to improve and adjust the school's safety processes. The captured knowledge was applied to school safety via the use of CEDAC. CEDAC is an acronym for cause and effect diagram with the addition of cards, and is used in groups to capture and organize knowledge so it can be used to improve processes and aspects of work. CEDAC is based on the fishbone or Ishikawa diagram and involve the capturing, coordinating and distributing knowledge in relation to a process (Carstensen and Sørensen, 1996). In this research, the CEDAC was used as a tool to capture tacit or

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embedded knowledge and transform it into explicit knowledge for use in the school safety improvement program. The causes of school safety issues were categorized into the five aspects of invitational theory (people, places, programs, policies, programs). These categories focused staff in thinking about how their tacit knowledge could be effectively applied to different aspects of school safety. Teachers and staff were first introduced to the concept of CEDAC and the school's safety, along with invitational theory. The teacher and staff were asked what aspects of people, places, programs, policies and processes were leading to reduced school safety. Figure 3.27 shows a blank CEDAC diagram, while Figure 3.28 captures the teachers and staff during the first RPIW and involved in the CEDAC process.

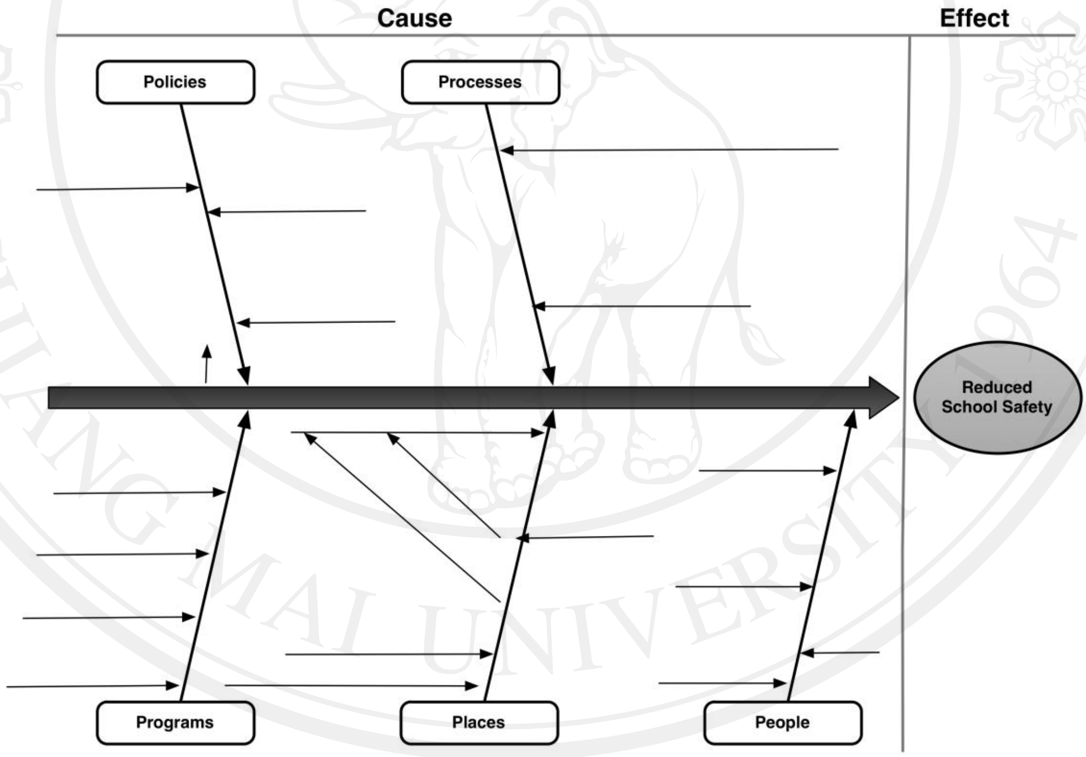

Figure 3.27 An example of a blank cause and effect (fishbone) diagram used to gather staff and teacher ideas regarding school safety

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Figure 3.28 The CEDAC exercise to involve staff in generating and sharing tacit and embedded knowledge related to school safety

After gathering data from the CEDAC diagram it was important to assess how this knowledge affected the school's safety, and how it could be linked to the earlier lean processes to improve school safety. This was achieved through an interrelationship digraph. Unlike the CEDAC, which simply captures and shows the causes and effects of poor school safety, an interrelationship digraph allows the identification of the most critical issues and more importantly, allows a distinction to be made between those issues that are drivers of poor school safety and those which are merely outcomes.

After generation of the CEDAC diagrams in the RPIW, the school management created an interrelationship digraph using the CEDAC causes as inputs to this process. Figure 3.29 shows an example of this interrelationship digraph.

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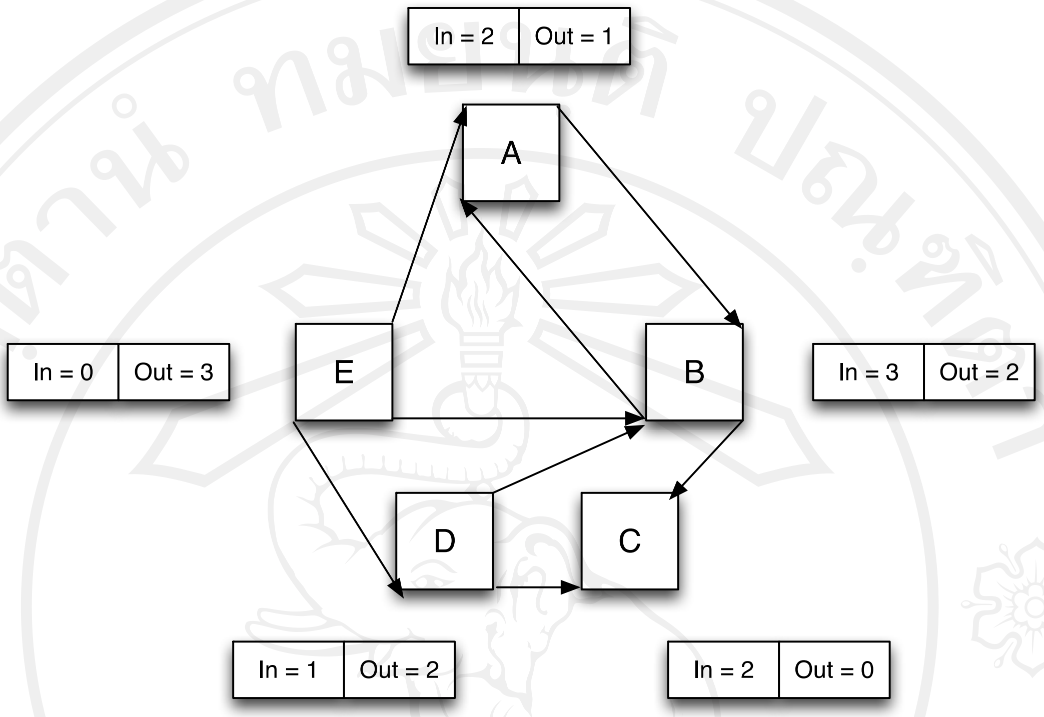

Figure 3.29 Example of the interrelationship digraph process

As shown in Figure 3.29, an interrelationship digraph is built by determining the inputs and outputs to each cause (shown as A-E in Figure 3.29). Once this process is complete, the arrows are tallied to identify which are root causes or drivers (high number of outgoing arrows) and which are outcomes (high number of incoming arrows). In the example in Figure 3.29, E is likely to be a driver or root cause, while C is primarily an outcome with mostly inputs, but no outputs.

The process exemplified in Figure 3.29 was completed for all the causes identified in the CEDAC diagrams to build a picture of the key drivers and outcomes of school safety. These represent the tacit and embedded safety knowledge that the teachers and staff possess. This knowledge was then combined with the knowledge collected from the earlier explicit data collection instruments to apply in synergy to improve school safety at the case study.

One of the key aspects of increasing school safety is knowledge sharing, and thus the second RPIW focused on knowledge sharing between teachers, staff, management and parents.

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3.8.10.3 RPIW Two: Knowledge Sharing Survey and Training Activities

The second RPIW focused on developing the knowledge sharing awareness of teachers and staff. The workshop lasted for one day and included presentations of the nature of knowledge sharing, the importance of knowledge sharing, and how knowledge sharing is critical for safety. Pretests and posttests were conducted as part of the knowledge sharing training activity. At the beginning of the training session, teachers and staff took a pretest to benchmark their understanding of knowledge sharing prior to the training session. Following the completion of the training session the same test was administered and thus acted as a posttest. Finally, a week after the training session, the test was once again undertaken to assess if the staff retained the knowledge over a longer timescale. In addition to the main group of staff and teachers, a control group, who did not attend the training, also conducted these tests. This ensured that the real effect of the training on the staff and teachers could be assessed. A paired t-test was then completed to assess the scores before and after the training (pre and post test). Equation 3.8 illustrates the standard procedure for calculating the paired t-test between the results of the pre, post and long-term post tests.

$$t = \frac{\bar{X}_D - \mu_0}{S_D/\sqrt{n}}$$

Equation 3.8 Calculation used to derive the **paired (dependent) t-test**

3.8.10.4 RPIW Three: Leadership and School Safety

The final of the three RPIWs involved training staff about leadership and how this affected school safety. Leadership is a critical aspect of effective school safety, and rather than a top down approach, the lean and knowledge management approach in this thesis promotes a bottom up management approach where teachers and staff are also involved in the leadership of school safety. As with RPIW Two, teachers and staff completed pretests, posttests and long-term posttests and there was also a control group. This enabled the effectiveness of the RPIW to be measured.

The three RPIWs were combined with the other aspects of the methodology to create the iceberg model of a lean knowledge management

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approach to school safety. The RPIWs generated, captured and stored tacit knowledge, while the earlier explicit data collection instruments allowed for the capture, organization and storage of the explicit aspects of school safety. In synergy, these create a new model of school safety, which was applied at the school. The approach is still ongoing, but after three months, it was assessed via a stakeholder analysis and other aspects to assess whether the lean knowledge management approach could be sustained.

3.9 Sustain Phase (Evaluation of the Solution)

This section outlines the data collection techniques in the sustain phase, and how they link to the overall conceptual framework. Figure 3.30 shows the data collection instruments and rationale behind this phase of the research.

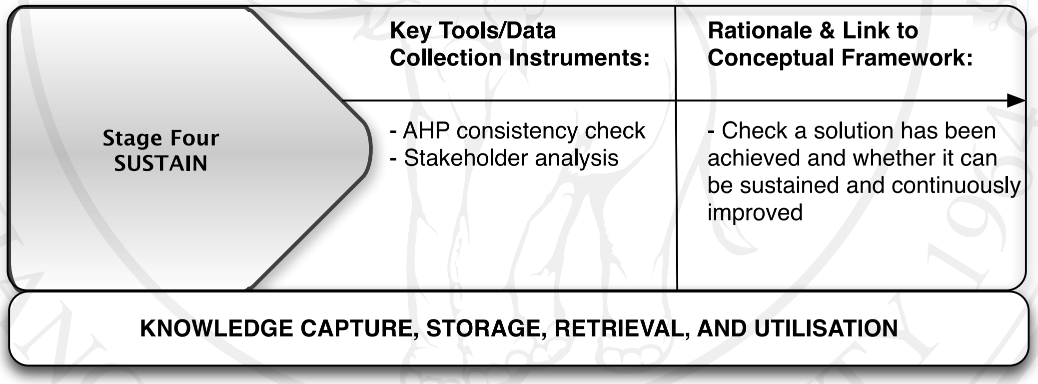

Figure 3.30 The scope phase of the research and the related tools and rationale

Figure 3.30 illustrates that the key tools in the sustain phase were the AHP consistency check, which sought to see how consistent (and therefore how usable and effective) the AHP model was. The solution was also evaluated via analysis from three key school stakeholders. The rationale behind these tools and this section of the research was to ensure that a solution had been achieved, and whether this solution to school safety was sustainable.

After the implementation of the previous solve phase, it was necessary to evaluate its effectiveness at improving school safety. The solution's effectiveness was evaluated in two main ways. Firstly, via some of the individual tools applied to school safety, for example the consistency of the AHP model in managing safety suggestions. The second evaluation, was from a wider perspective and was undertaken via stakeholder analysis from the perspective of key school stakeholder. This allowed for an evaluation of the solve phase of this research, as well as

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investigating how the solution can be sustained and continuously improved in the future. A key aspect of lean thinking is sustaining and continually improving the approach (Womack and Jones, 1992), thus during the evaluation, it was important to determine how the solution could be sustained and what might be done in the future to continuously improve school safety. The evaluation method is now explained from the two main perspectives, which are the evaluation of individual tools, and the overall stakeholder evaluation.

3.9.1 Evaluating Individual Tools in the Solution

One of the key tools in the solution is the AHP model for managing school safety suggestions. To be effective in terms of standardizing and sorting school safety suggestions, the AHP model must be consistent in terms of giving the same output score to suggestions no matter who the user, and should also remain consistent over time. In other words, the consistency of the AHP model should be independent of people and processes at the school. To assess this consistency, a series of safety suggestions were given to one of two groups. These groups were as follows:

- **Group one:** five staff and teachers selected at random and asked to assess five safety suggestions using the AHP model.
- **Group two:** five staff and teachers selected at random and asked to assess safety suggestions without any guidance, and without using the AHP model

The first group used the AHP model, while the second group scored suggestions based on the currently entrenched system of simply assessing the suggestions qualitatively. These two groups were compared to see how variable the safety suggestion decisions were, and which method provided most consistency between differing users.

Based on the responses from the two groups, a coefficient of variation was calculated, which showed how variable the safety suggestion decisions were. This coefficient of variation allowed a determination to be made as to how effective the AHP model was in terms of standardising the decision making process for school safety suggestions. As well as assessing the AHP model for consistency, it was also evaluated in a more qualitative way at the same time as the stakeholder analysis.

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3.9.2 Evaluation via Stakeholder Analysis

The stakeholder analysis took place with three main school stakeholders:

- School Management (School Director, School Manager)
- School Teachers and Staff (10 teachers, 5 staff)
- Parents (10 parents)

Each of these stakeholder groups was questioned separately via a one-hour focus group in order to assess their views on the new approach to school safety. There were three main areas of attention during the focus groups, which were:

1. The AHP model and its ease of use and effectiveness at dealing with multiple safety related suggestions in the school.
2. The new safety related processes, which have been adapted based on the lean value stream mapping, as well as the 5S and 7 wastes.
3. The effectiveness of the three RPIWs.
4. The overall effectiveness of the lean knowledge management approach to school safety.

Together, these focus groups allowed for an overall evaluation of the new approach to school safety. While quantitative measures such as the school's accident records could be utilized, there are a variety of reasons why using statistics to measure the effectiveness of safety is a fallacy. The evaluation was also conducted shortly after the implementation of the new safety approach, and thus there had not been enough time for there to be a visible effect on the quantitative measures of school safety.

3.10 Chapter Summary

Figure 3.31 indicates the key methodological steps undertaken to complete this research, including their order and approximate timescales.

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	Methodological Steps	Scope Phase- Approx. 3 Months			Select Phase- Approx. 6 Months						Solve Phase - Approx. 6 Months						Sustain Phase- Approx. 3 Months		
1	**Scope Phase**	■	■	■															
2	Literature	■																	
3	Questionnaires - 5 schools in northern Thailand		■																
4	Analysis			■															
5	**Select Phase**				■	■	■	■	■	■									
6	Questionnaires at case study				■	■													
7	In-depth interview at case study					■	■												
8	UML model of safety process							■	■										
9	Hazard Assessment								■	■									
10	**Solve Phase**										■	■	■	■	■	■			
11	Value Stream Mapping										■	■							
12	5s											■	■						
13	7 Wastes											■	■	■					
14	AHP													■	■				
15	RPIWs														■	■			
16	**Sustain Phase**																■	■	■
17	Evaluating Tools																■	■	■
18	Stakeholder Analysis																	■	■

Figure 3.31 The key methodological steps to develop, implement, and evaluate the lean Knowledge Management approach to the school safety

This chapter has presented the methodological foundation of this research, and began by highlighting the conceptual framework and the novelty of the knowledge management approach. It has shown how knowledge management and school safety are well matched in terms of KM's tools/expertise, and the related needs of school safety. The chapter introduced the iceberg conceptual model to highlight the tacit and explicit aspects of school safety, and how knowledge management can act as a foundation, bringing together tacit and explicit aspects of school safety, while lean tools can be applied to these tacit and explicit processes in order to cut waste and improve efficiency. The main part of this chapter then detailed the methodological processes and steps according to the scope, select, solve and sustain framework. The main tasks and tools in each step were explained and justified. Now the conceptual framework and methodological steps have been detailed, Chapter 4 presents the key results from the research.

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