CHAPTER 6

DECISION SUPPORT SYSTEM FOR NOISE HAZARD PREVENTION

A decision support system (DSS) program for noise hazard prevention (NHP) is presented in this chapter. The heuristics and genetic algorithms described in previous chapter are utilized to determine the *near-optimal* solution. The conceptual design of the DSS for NHP and modules of DSS are discussed in this chapter.

6.1 Conceptual Design

A decision support system for noise hazard prevention (NHP) is developed in Microsoft Access using Visual Basic for Application (VBA). Briefly, the NHP program consists of four modules, namely, Database, Input, Solution Algorithms, and NHP Solution. The *Database Module* stores the machine data, engineering noise control technique data, and HPD data. The *Input Module* provides a user-friendly interface between the user and the NHP program to assist him/her in inputting additional data and a desired solution procedure. The user may choose to follow the OSHA's hierarchy of noise control or choose the noise control procedure based on their preference. The *Solution Algorithms Module* is designed to utilize heuristic and genetic algorithms to generate a *near-optimal* noise hazard prevention solution according to the selected solution procedure and allocated budget. Finally, the *NHP Solution Module* presents a noise hazard prevention solution that includes the recommended noise control techniques and the resulting daily noise exposures of all workers. The flow chart of the NHP program is shown in Fig. 6.1

6.2 The Database Module

The *Database Module* is called a general input module of the NHP program. It contains the machine data, engineering noise reduction (at the source) applicable for individual noise sources, engineering noise reduction (along the path) or the noise barrier data, and HPD data. It is imperative that the user must firstly enter the necessary information of the workplace before visiting the other three modules. Table 6.1 shows the four categories of workplace data that must be entered into the database of the NHP program. Readers should note that for each noise control project, relevant workplace data will be retrieved from the database to be used in the *Solution Algorithms Module* to generate the NHP solution. Figs. 6.2 to 6.5 show the blank form of the database module.

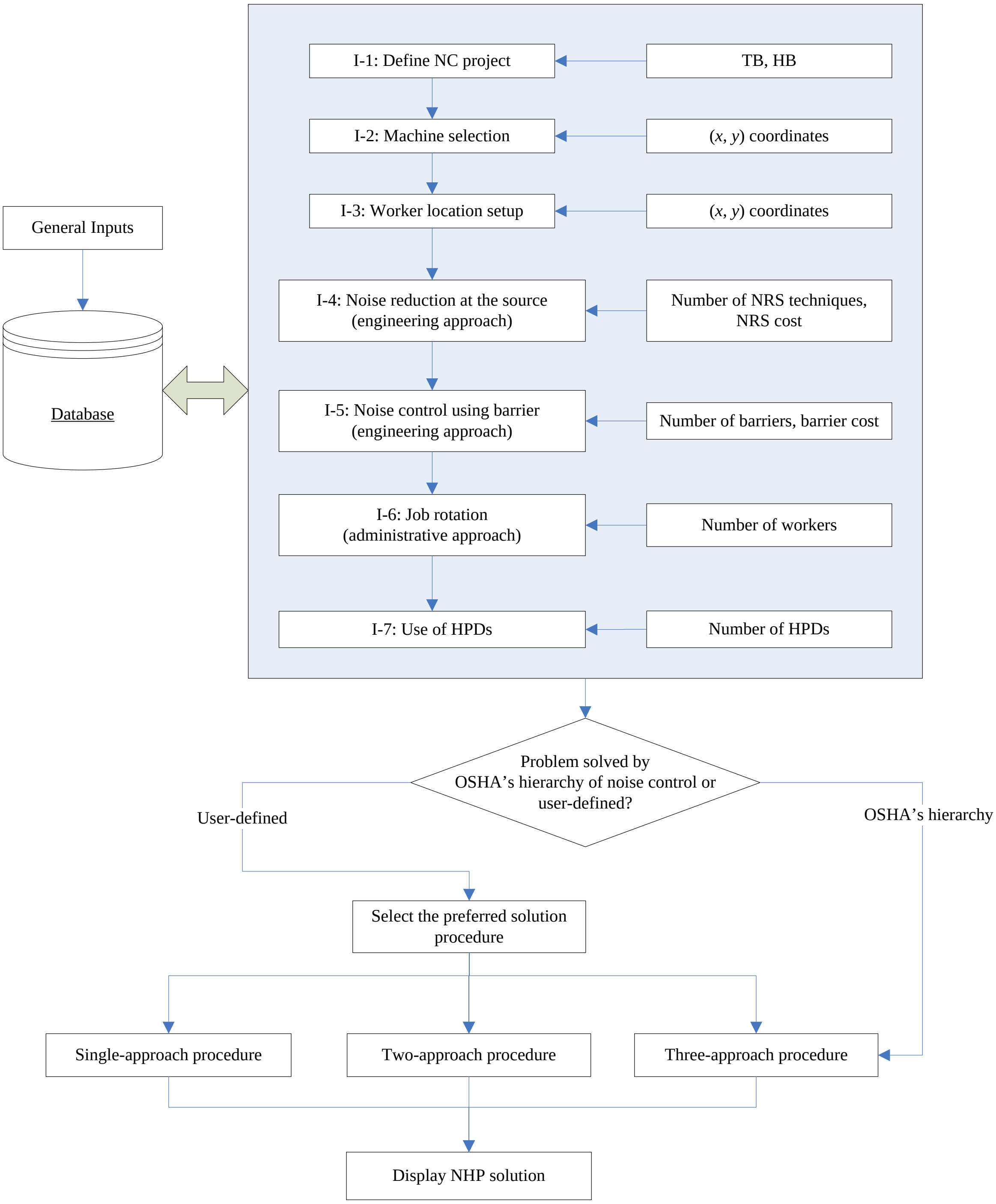


Fig. 6.1 Flow chart of the NHP program

Table 6.1 Information required for the general input

Category	Required Information
Machine Data	• Machine ID • Machine Type/Description • Machine Noise Level (dBA)
Engineering Noise Reduction (at the Source) Data	• NRS ID • NRS Technique Description
Noise Barrier Data	• Noise Barrier ID • Noise Barrier Type/Description
HPD Data	• HPD ID • HPD Type/Description • HPD Cost

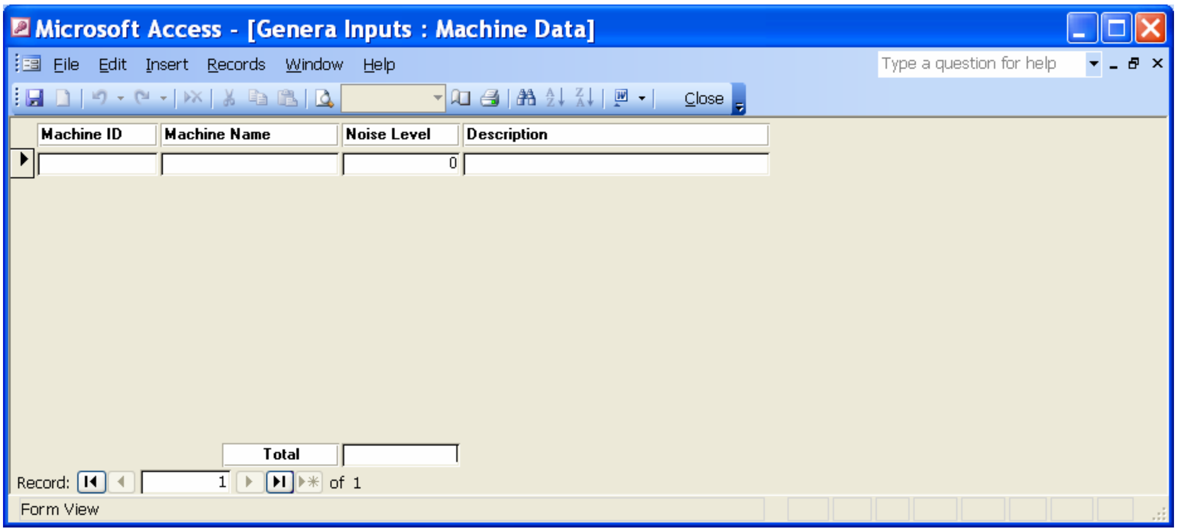


Fig. 6.2 Blank form of machine data

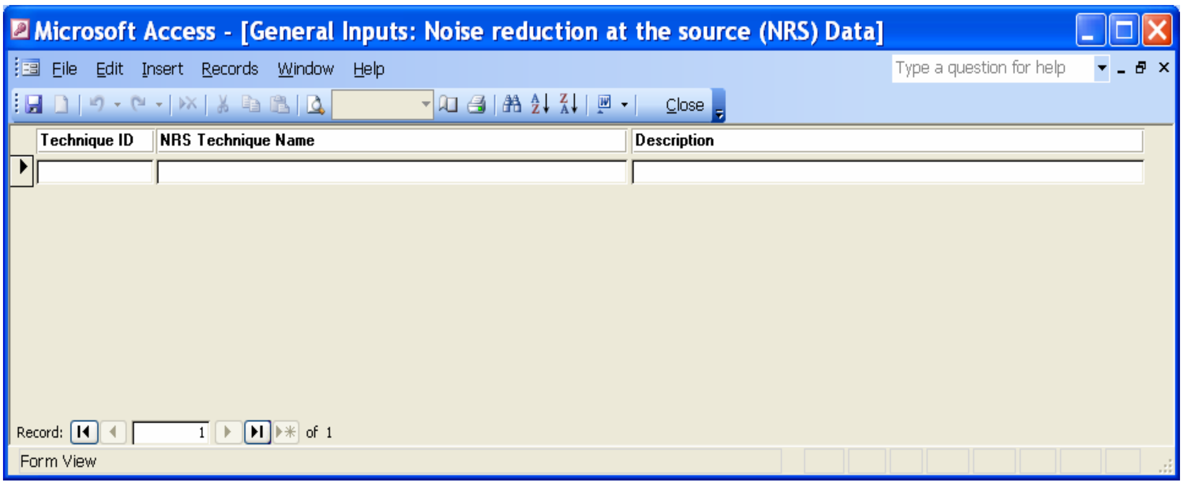


Fig 6.3 Blank form of noise reduction at the source (NRS) data

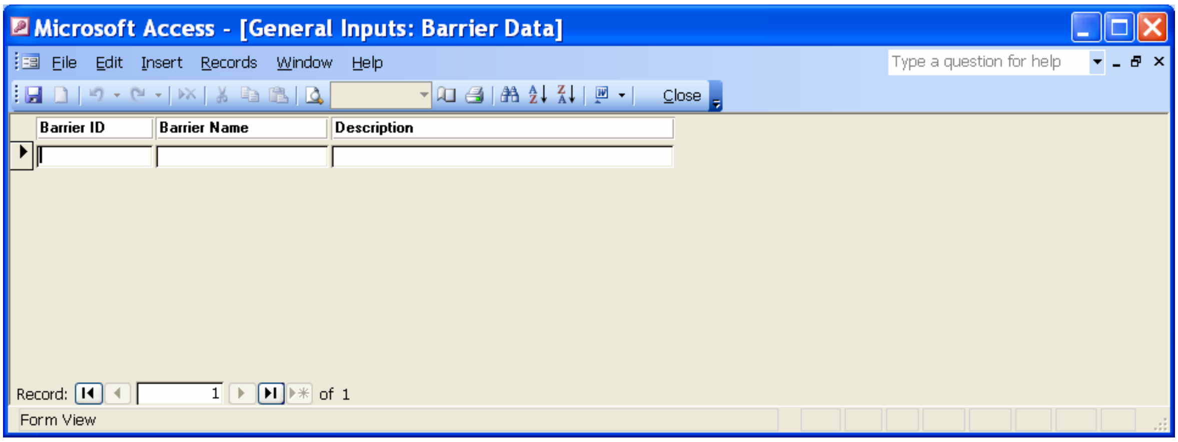


Fig 6.4 Blank form of noise barrier data

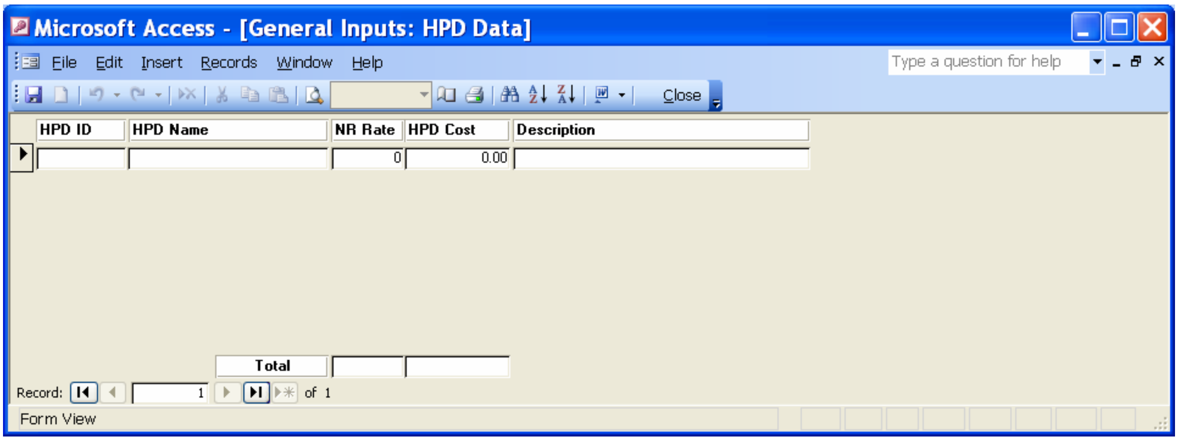


Fig 6.5 Blank form of HPD data

6.3 The Input Module

The *Input Module* of the NHP program enables the user to create the "noise control" project, or NC project. Each NC project is basically a noise control problem. For a given workplace, the user may create several NC projects, depending on the size and scope of the project. Necessary information can then be retrieved from the NHP database. Next, additional necessary data such as machine location data, worker location data, applicable noise control techniques, cost data, and noise control budget will be entered. The following steps describe the sequence of actions that the user usually performs when creating a NC project.

Step 1: Firstly, the user can choose either to create a completely new NC project or to retrieve an existing NC project. If the new NC project is to be created, the user must enter the project ID, project name and description, total noise control budget (*TB*), and HPD budget (*HB*).

Step 2: After defining the new NC project, the user has to select the machines from the database to be included in the NC project. For each machine, the user also needs to specify the machine location in terms of the *x*-coordinate and *y*-coordinate.

Step 3: Next, applicable NRS techniques can be added to each selected machine. For a machine, it is possible to have several NRS techniques that can be applied to reduce the machine noise. It is also necessary to define the noise reduction rating (NRR), in dB*A*, and cost of each NRS technique.

Step 4: The worker locations (*x*-coordinates and *y*-coordinates) are then defined.

Step 5: If the noise barrier can be applied, the user can retrieve the noise barrier ID, and noise barrier description from the database. For the noise barrier cost and NRR, the user has to enter the data in this step.

Step 6: If the number of available workers to be included in the NC project is greater than the number of worker locations, it can be specified in this step.

Step 7: The last step is to select HPDs to be used in the NC project. The HPD data can be retrieved from the database.

The blank form of a noise control project is displayed in Fig. 6.6.

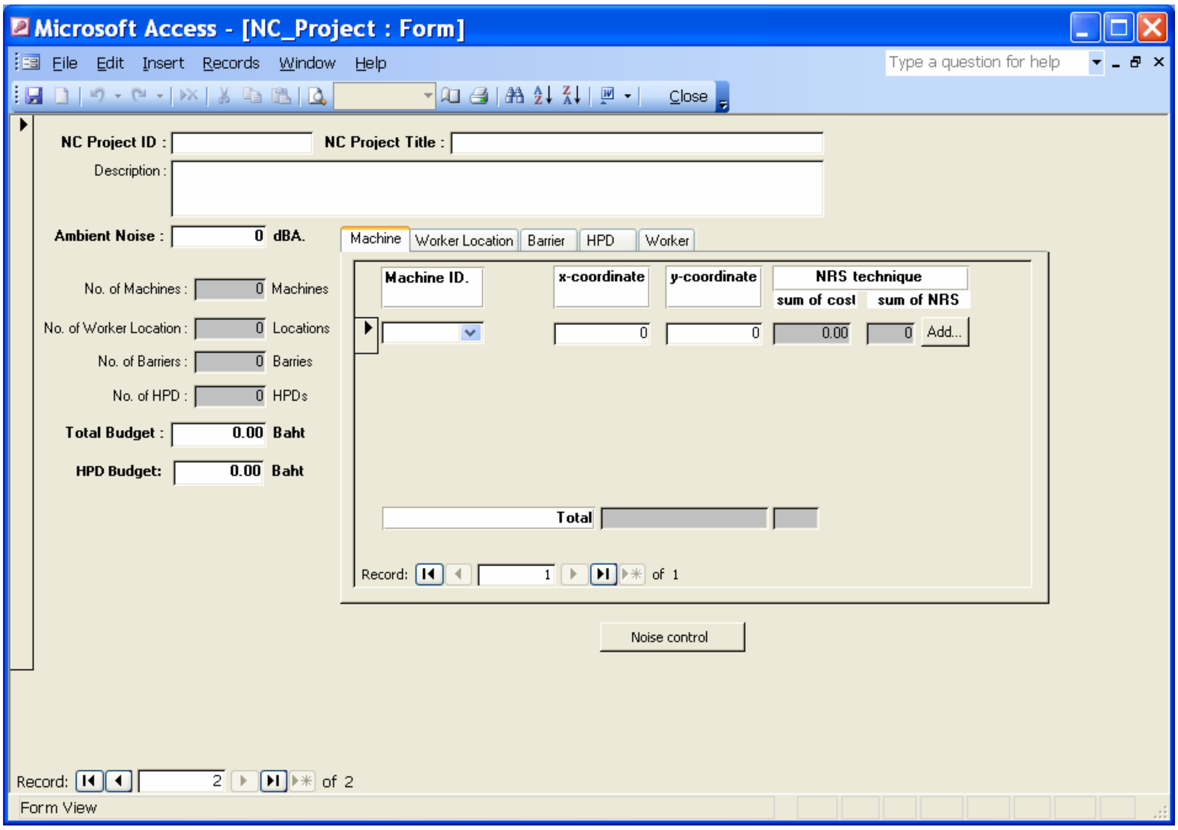


Fig 6.6 Blank form of noise control project

6.4 The Solution Algorithms Module

The next module is the *Solution Algorithms Module*. The main function of the *Solution Algorithms Module* is to perform necessary computations based on pre-specified noise control approaches and solution procedures and to determine the resulting noise exposures of all workers.

Consider a workplace where workers are present at various locations during an 8-hour workday. Since there usually are several noise sources and workers may not stay at one location, it is necessary to determine an 8-hour time-weighted average (8-hour TWA) sound level that each worker receives.

To prevent the daily noise exposure from exceeding 90 dB*A*, the total noise load that any worker receives within an 8-hour workday must not be greater than 1.

6.4.1 Algorithms for Engineering Controls

As stated earlier, the NHP program considers only controlling at the noise source and along the path (blocking the noise transmission path by barriers). Controlling at the noise source implies that the machine noise is reduced, and all worker locations will benefit from such noise reduction. Controlling along the path, however, will reduce the noise level at some worker locations (only those locations that the barrier can block the noise transmission path).

From the available engineering noise control techniques, the selection of appropriate engineering controls can be formulated as cost-based and safety-based models (Asawarungsaengkul and Nanthavanij, 2005). The cost-based model is intended to *minimize the total cost* when applying feasible engineering controls (i.e., reducing the machine noise and/or blocking the noise transmission path by barriers) such that the combined noise level at any worker location does not exceed 90 dB*A*. The safety-based model, on the other hand, is intended to *minimize the maximum noise load per work period* among all worker locations such that the resulting total cost does not exceed the allocated engineering control budget (EB).

To enhance the practicality of the NHP program, a GA version of the cost-based and safety-based models is used instead of the mathematical programming (Asawarungsaengkul and Nanthavanij; 2007). For more details on the GA approach to the selection of engineering noise controls, see Chapter 4.

6.4.2 Algorithms for Administrative Controls

The only administrative control technique considered in the NHP program is an application of job rotation to rotate workers among worker locations so that the maximum daily noise exposure that any worker receives does not exceed 90 dB*A*. Workers are allowed to rotate to other worker locations only at the end of the work period.

Two mathematical models are developed for administrative controls. The first model (Model A1) is intended to determine a set of feasible work assignments for the current workforce such that the total worker-location changeover is minimized. The worker-location changeover occurs when a worker moves from one worker location to another. To some extent, productivity might be affected due to possible needs for learning and adapting to a new task. Thus, it is necessary to keep the number of worker-location changeovers as few as possible.

The second mathematical model (Model A2) considers the situation in which additional workers are required for job rotation due to excessive noise levels in the workplace. The model objective is to determine the minimum number of workers (in the workforce) to be rotated among the given worker locations such that none of the workers receives the daily noise exposure beyond 90 dB*A* (Asawarungsaengkul and Nanthavanij, 2005). The important assumptions for implementing job rotation can be found in Chapter 3.

Similar to the selection of engineering noise controls, a GA version of the job rotation models is used instead of the mathematical programming. The algorithm uses heuristic crossover and mutation to improve the efficiency of GA. The hybrid procedure developed by Yaoyuenyong and Nanthavanij (2004) is used to generate an initial population. For more details of GA for workforce with minimum worker location changeover, see Chapter 5.

6.4.3 Algorithms for the Use of HPDs

The use of HPDs should be considered as a supplementary noise control approach. That is, it should be applied only if engineering and administrative controls fail to prevent the workers' daily noise exposures from exceeding the permissible limit. Additionally, the number of worker locations where the use of HPDs is required should be as few as possible. In practice, HPDs should be worn only at the worker locations that are very noisy.

Two mathematical models for selecting appropriate HPDs are available (Asawarungsaengkul and Nanthavanij, 2005). Both models consider job rotation and the use of HPDs concurrently. The first model (Model H1) is intended to determine the minimum number of HPDs based on the given HPD budget (*HB*) and the current workforce. The model also yields the type of HPD and the worker location where the HPD must be worn. The second model (Model H2) is used to determine the minimum number of HPDs when the current workforce and additional workers are considered for job rotation.

The GA approach stated in the previous section can be utilized in conjunction with a heuristic algorithm to select the minimum number of HPDs as well. In brief, the algorithm procedure comprises two phases: (1) to find the minimum number of HPDs, and (2) to find the optimal work assignments. These phases are described as follows.

Phase 1: Find the minimum number of HPDs

The heuristic consists of the following five steps:

Step 1: Rank all HPDs in descending order of the HPD cost. The HPD that has higher cost than others must also have higher NRR. Otherwise, it will be eliminated from the HPD list.

Step 2: Rank all worker locations in descending order of the combined noise level.

Step 3: Start at *level* 1 (at the worker location having rank No.1). At *level* 1, all available HPDs from Step 1 are considered.

Step 4: Calculate the HPD budget (*HB*) and the lower bound of the required number of workers for each branch. The calculation of the lower bound can be found in Yaoyuenyong and Nanthavanij (2004). The branch having the total HPD cost greater than HB is bounded. If there exists a branch that has the lowest lower bound, its total HPD cost not exceeding *HB*, and the lower bound not exceeding the available number of workers, go to Step 5. Otherwise, go to Step 6.

Step 5: Calculate new w_j for all worker locations and apply the heuristic developed by Yaoyuenyong and Nanthavanij (2004) to find the minimum number of workers. If the number of workers does not exceed the available number *M*, go to Step 7. Otherwise, go to Step 6.

Step 6: Set *level* = *level* + 1. At *level* > 1, each node can be branched by starting at the node No. from the parent node until the node No. is equal to the number of available HPDs (excluding the HPDs that are eliminated in Step 1). After that, return to Step 4.

Step 7: Set the number of HPDs required for noise control equal to *level* and stop the procedure. The branch having the lowest cost will be selected.

Phase 2: Find the optimal work assignments

Calculate new w_j for all worker locations and utilize the GA approach stated in Section 6.4.2 to find the minimum number of worker and total worker-location changeover.

Fig. 6.7 shows the procedure of Phase 1 that determines the minimum number of HPDs required for the noise control when job rotation is also applied. In Fig. 6.7, there are three levels that means three HPDs will be used at worker locations having the top three noise levels. It is also seen that the right hand side branch having the lowest cost is the solution of Phase 1 and HPD with ranking (of cost) No. 3 are selected to wear at three worker locations.

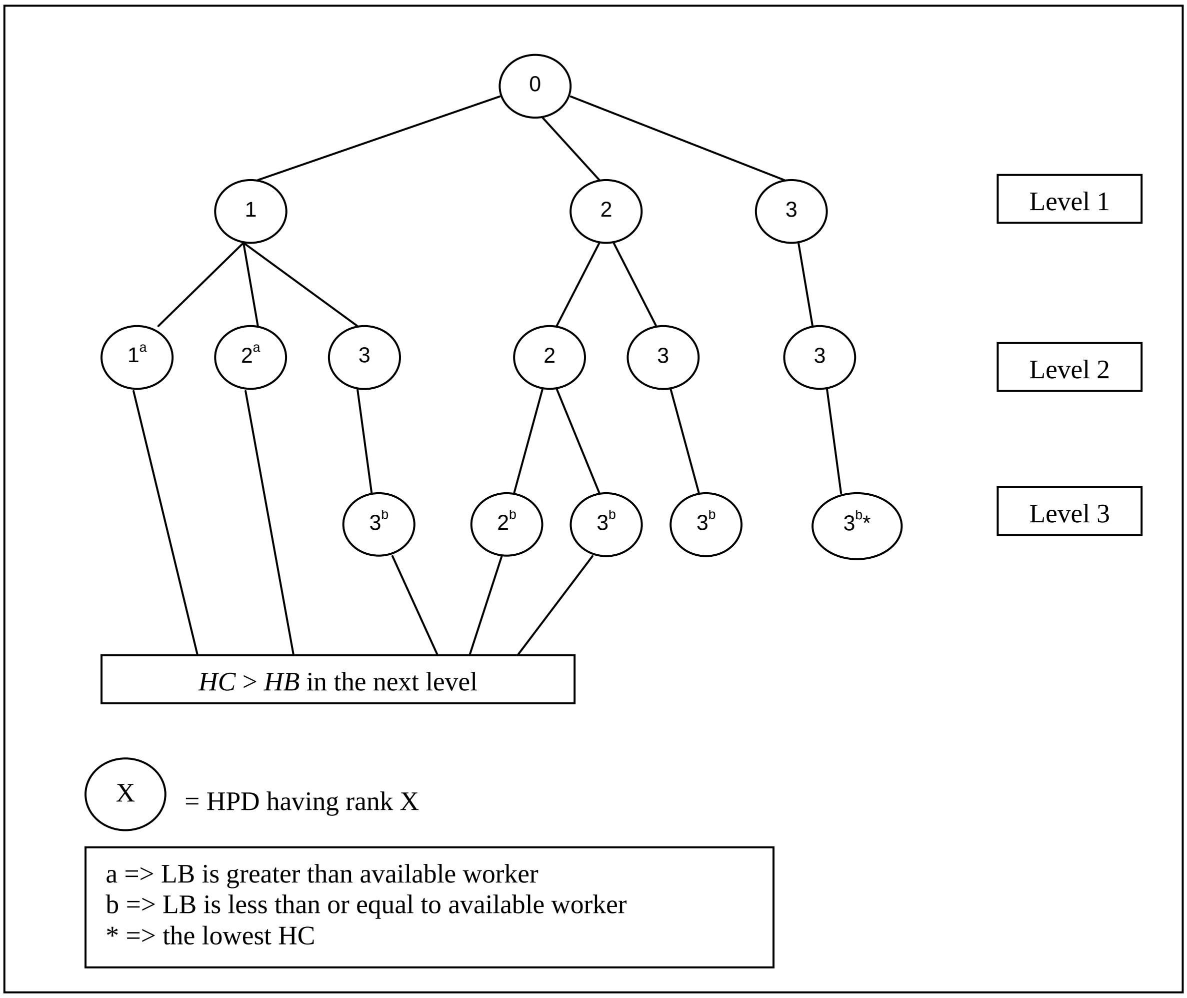


Fig 6.7 Heuristic for finding the minimum number of HPDs

6.4.4 Solution Procedures

The NHP program allows the user to choose the solution procedure that most suits his/her preference. There are three built-in solution procedures. The first and second procedures also contain three sub-options, as shown below.

1. Single-approach procedure
    - Engineering approach
    - Administrative approach
    - The use of HPDs
2. Two-approach procedure
    - Engineering-administrative approach
    - Engineering-HPDs approach
    - Administrative-HPDs approach
3. Three-approach procedure

For the three-approach procedure, the OSHA's hierarchy of control is followed. Figs. 6.8 to 6.10 show the flow charts of the three solution procedures that are available in the NHP program. It should be noted that if the noise control budget is insufficient, the *Solution Algorithms Module* will automatically search for the noise hazard prevention solution that is effective, determine the total cost, and recommend it as the minimum required noise control budget.

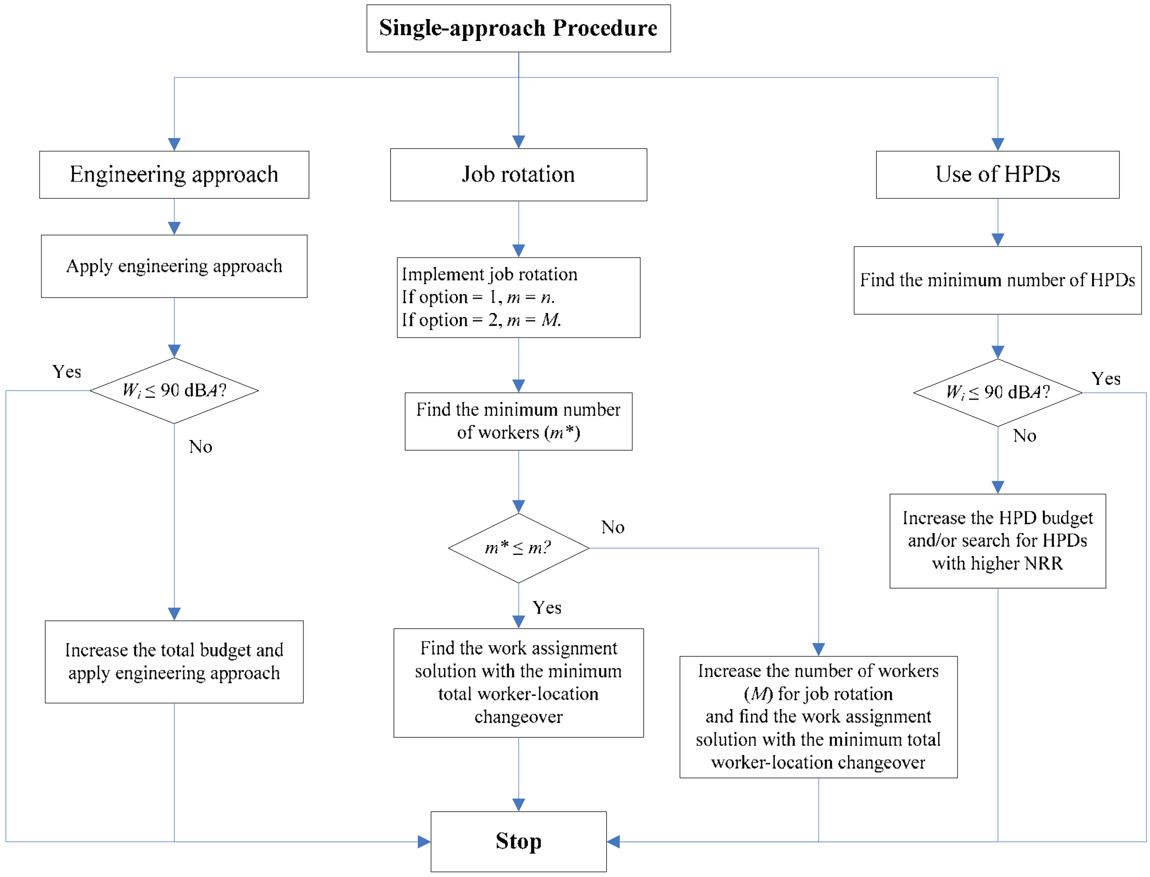


Fig. 6.8 Flow chart of the single-approach procedure

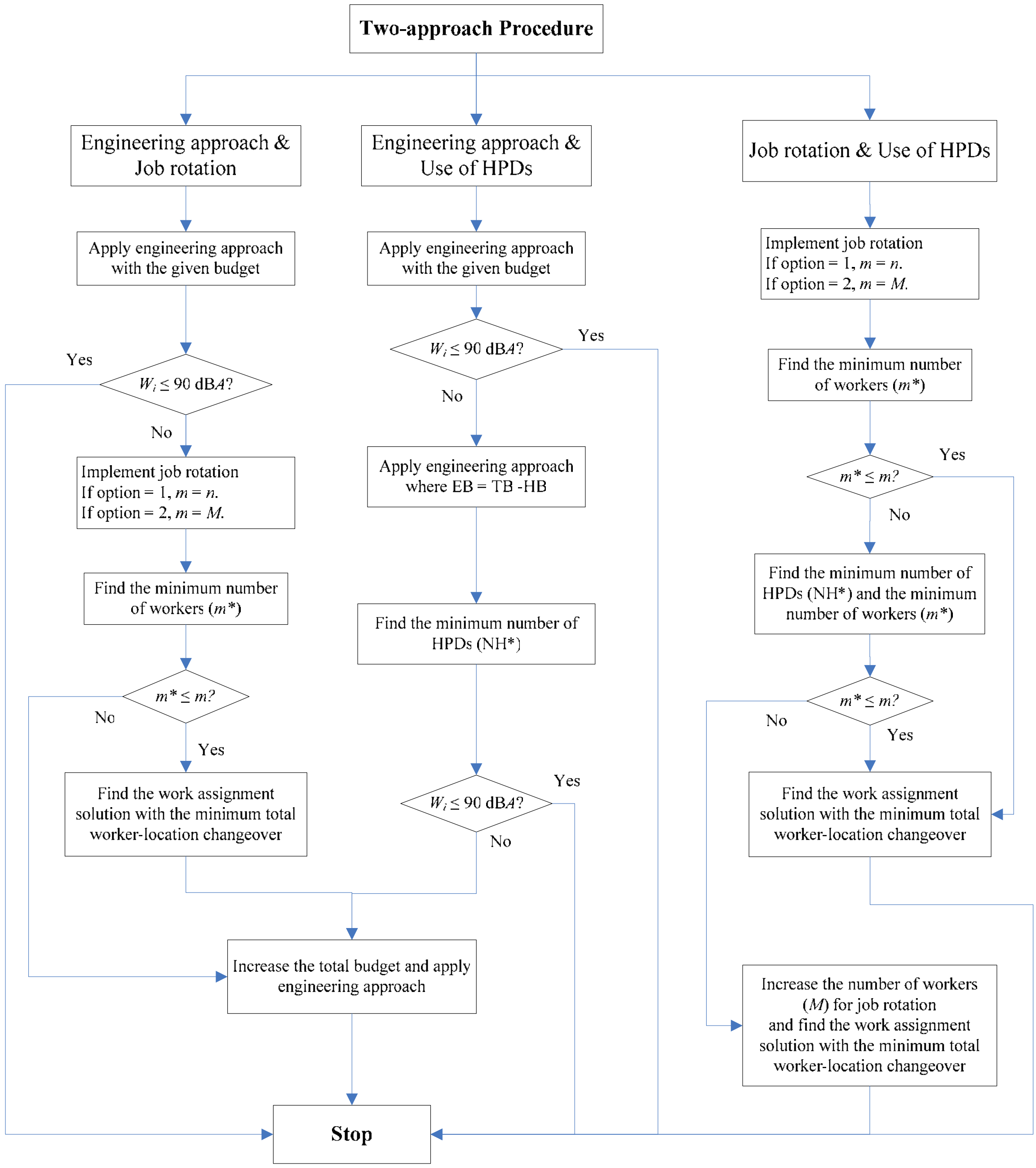


Fig. 6.9 Flow Chart of the two-approach procedure

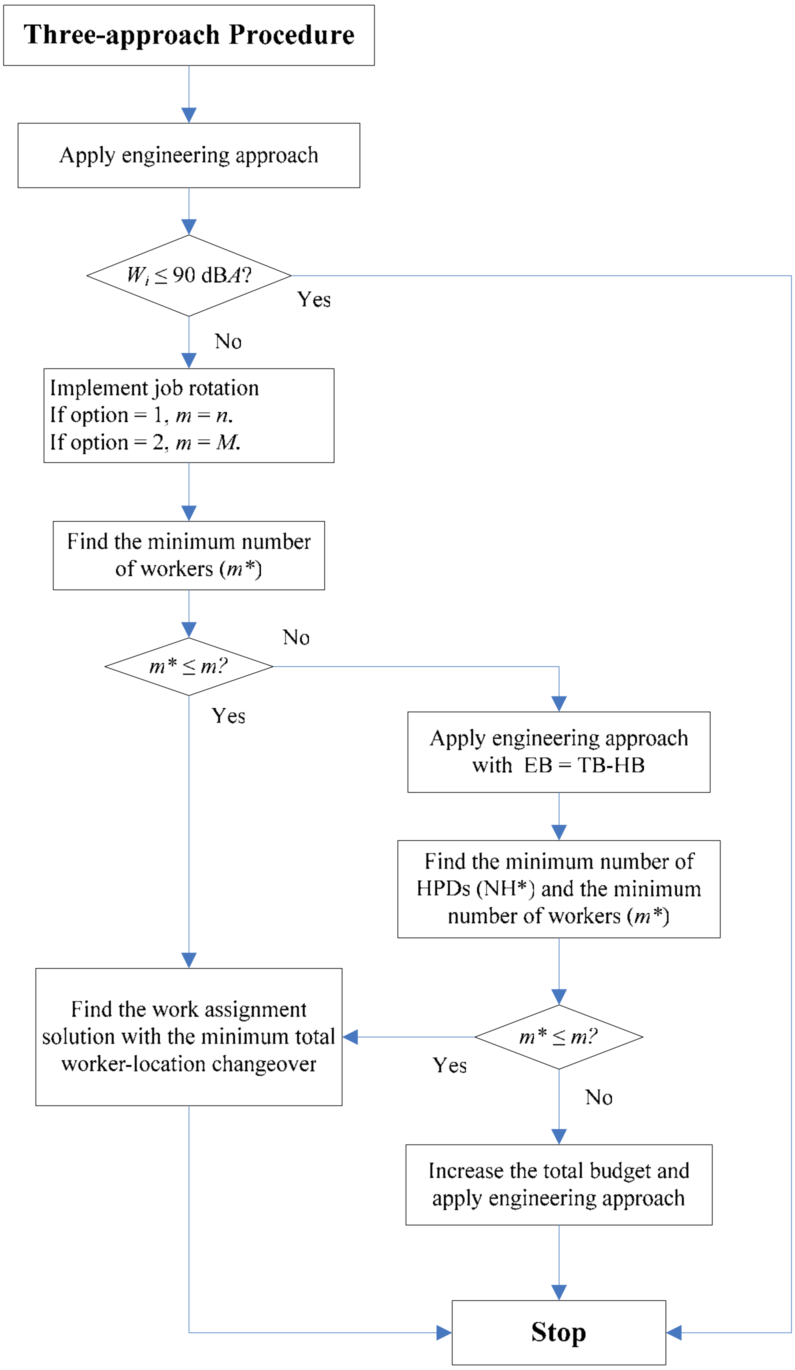


Fig. 6.10 Flow Chart of the three-approach procedure

6.5 The NHP Solution Module

The last module of the NHP program is the *NHP Solution Module*. After finding an effective noise hazard prevention solution based on the given noise control budget and the preferred solution procedure, the NHP program will generate the NHP report using the *NHP Solution Module*. For each worker location, both the present noise level and the reduced noise level are the default solution displayed by the *NHP Solution Module*.

Specifically, the details of the NHP solution report depend on the noise control approach selected in the *Solution Algorithms Module*, as summarized below.

1. Engineering approach
   - Required NRS techniques and noise barriers
   - Cost of individual engineering controls
2. Administrative approach
   - Work assignment solution with the minimum total worker-location changeover
   - The minimum number of workers for job rotation
3. The use of HPDs
   - Required HPD for each worker location
   - Cost of HPD

The *NHP Solution Module* also generates an electronic output file for each NC project. If the NHP solution within the given noise control budget cannot be found, a feasible NHP solution with an increased budget (if the engineering approach is to be applied) or an increased number of workers (if job rotation is to be implemented) will be added to the end of the output file.

6.6 Illustration of NHP Program

A production facility has eight machines (M1, M2, …, M8) that are operated on a full-time basis. At present, there are six workers (W1, W2, …, W6) being assigned to six different worker locations (WL1, WL2, …, WL6) in this workplace. The ambient noise level in the facility is 70 dB*A*. Table 6.2 shows location coordinates of the eight machines, their noise levels, and location coordinates of the six worker locations.

Table 6.2 Machine location coordinates, noise levels, and worker location coordinates

Machine	Location Coordinate (m)		Machine Noise (dB*A*)	Worker Location	Location Coordinate (m)	
	x-coordinate	*y*-coordinate			*x*-coordinate	*y*-coordinate
M1	3	3	94	WL1	3	4.5
M2	6	3	85	WL2	12	4.5
M3	9	3	88	WL3	3	7.5
M4	12	3	95	WL4	6	7.5
M5	3	9	94	WL5	9	7.5
M6	6	9	92	WL6	12	7.5
M7	9	9	93			
M8	12	9	93			

From the given machine noise data, the combined noise levels at the six worker locations are found to be 91.59, 92.37, 91.82, 91.29, 91.68, and 91.31 dB*A*, respectively.

Suppose that each worker is assigned to one worker location and job rotation is not implemented. It is clear that all six workers are exposed to a noise hazard condition since their daily noise exposures exceed the permissible level. An effective noise hazard prevention program is required to reduce their daily noise exposures. If necessary, two additional workers can be assigned to work in this facility. Also, to implement job rotation, an 8-hour workday is divided into four equal work periods.

Table 6.3 shows two engineering control techniques for reducing machine noise at individual machines, costs, and noise reduction levels. Furthermore, there are two types of noise barrier for blocking the noise transmission path. Type-1 noise barrier costs 15,000 baht (where 40 baht is approximately 1 USD) and it reduces the noise levels at worker locations WL1 and WL3 by 4 and 8 dB*A*, respectively. Type-2 barrier costs 15,000 baht, and it reduces the noise levels at worker locations WL2 and WL6 by 4 and 8 dB*A*, respectively. There are two types of HPD, type-A and type-B, which can be worn at any of the six worker locations. Type-A HPD costs 100 baht and its effective NRR is 8 dB*A*. Type-B HPD costs 500 baht, with an effective NRR of 12 dB*A*.

Table 6.3 Techniques for reducing machine noise, costs, and noise reduction

Machine	NRS Technique 1		NRS Technique 2	
	Cost (baht)	Noise Reduction (dB*A*)	Cost (baht)	Noise Reduction (dB*A*)
M1	6,000	10	12,000	12
M2	7,500	8	-	-
M3	7,500	8	-	-
M4	9,000	9	16,000	15
M5	9,500	10	14,500	13
M6	10,000	8	18,000	12
M7	11,000	12	15,000	15
M8	8,000	7	13,000	11

Management has set the total noise control budget (*TB*) at 30,000 baht, with the budget for HPDs (*HB*) at 1,000 baht. The NHP program is used to design an effective noise hazard prevention program for this production facility. The following seven different cases are evaluated by the NHP program.

Case NC-1: Engineering approach, job rotation, and the use of HPDs
Case NC-2: Engineering approach and job rotation
Case NC-3: Engineering approach and the use of HPDs
Case NC-4: Job rotation and the use of HPDs
Case NC-5: Engineering approach
Case NC-6: Job rotation with additional workers
Case NC-7: The use of HPDs

Initially, the *Database Module* (General input) must be visited to create a database of the facility. By clicking at the symbol in front of the data category (Fig. 6.11), the user will see the data entry page that will allow them to enter the data into the NHP database.

After finishing entering data into the database, the user can then visit the *Input Module* to create a noise control (NC) project. Since management is interested in exploring the seven cases, seven NC projects (one NC project for each case) need to be created. Fig. 6.12 shows the data entry page of the *Input Module*. The user can either retrieve certain data from the database or enter new data into the NHP program.

Next, the user can visit the *Solution Algorithms Module* to choose the preferred solution procedure (see Fig. 6.13). Readers should note that the two engineering control techniques can be chosen at the same time, while only one job rotation option can be chosen at a time.

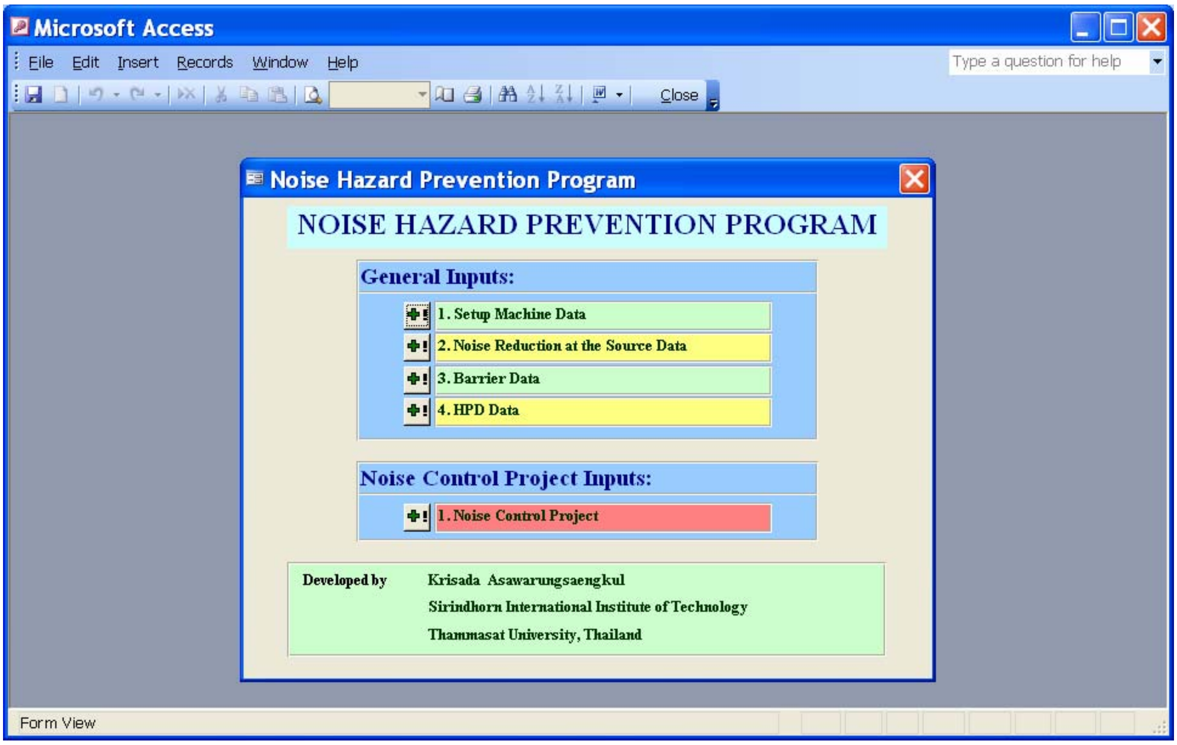


Fig. 6.11 The main menu of the NHP program

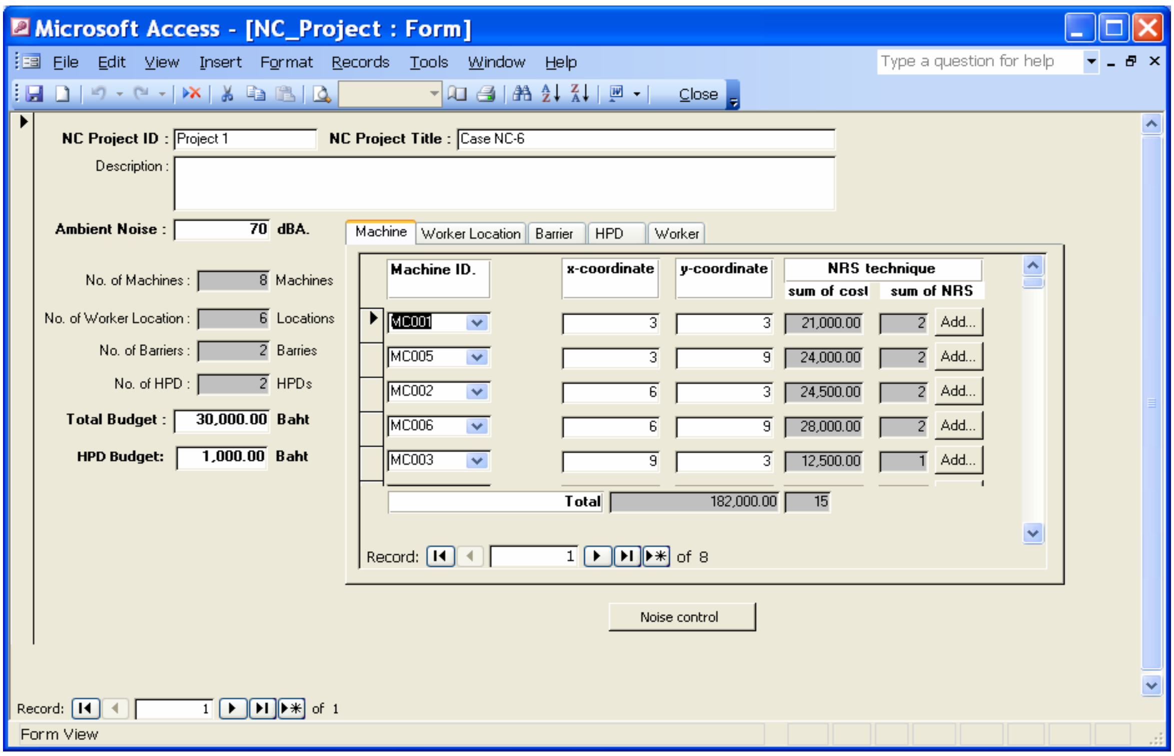


Fig. 6.12 Data entry page of the *Input Module* of the NHP program (Case NC-6)

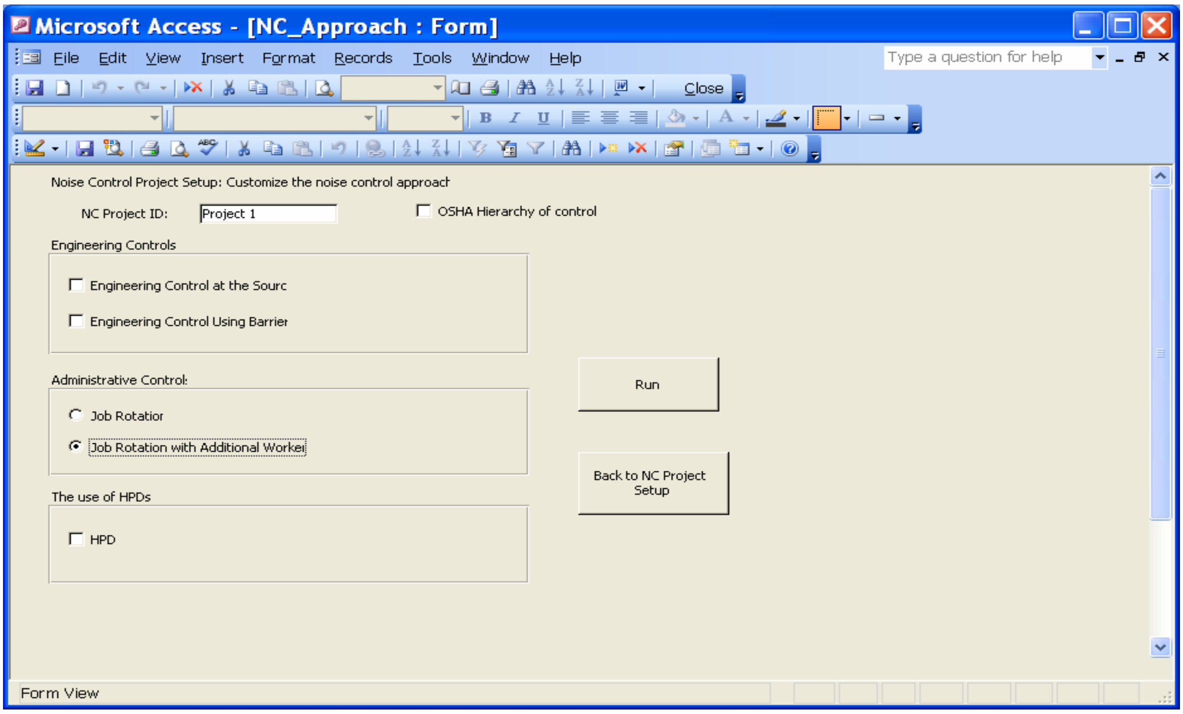
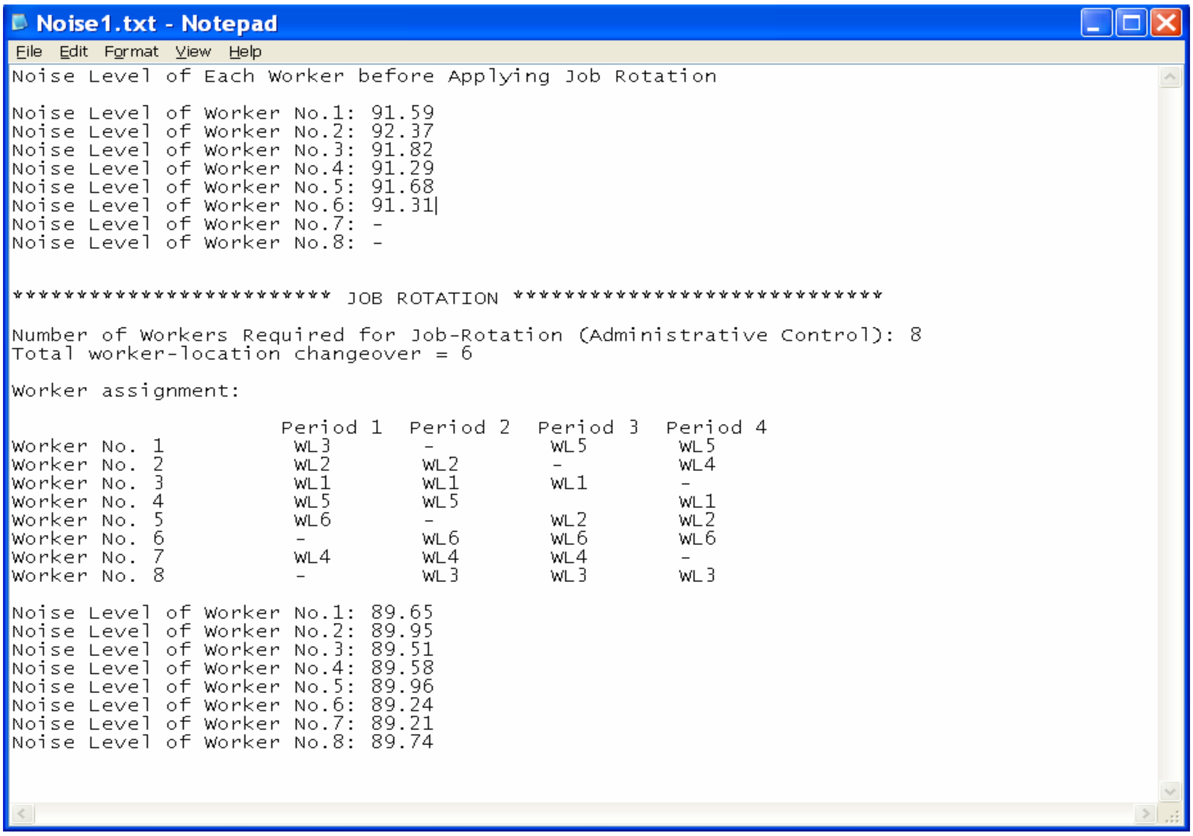


Fig. 6.13 Data entry page of the *Solution Algorithms Module* (Case NC-6)

Fig. 6.14 shows an example of the solution report generated by the *NHP Solution Module* for Case NC-6 (job rotation with additional workers).



Noise Level of Each Worker before Applying Job Rotation

Noise Level of Worker No.1: 91.59
Noise Level of Worker No.2: 92.37
Noise Level of Worker No.3: 91.82
Noise Level of Worker No.4: 91.29
Noise Level of Worker No.5: 91.68
Noise Level of Worker No.6: 91.31
Noise Level of Worker No.7: -
Noise Level of Worker No.8: -

************************* JOB ROTATION *****************************

Number of Workers Required for Job-Rotation (Administrative Control): 8
Total worker-location changeover = 6

Worker assignment:

	Period 1	Period 2	Period 3	Period 4
Worker No. 1	WL3	-	WL5	WL5
Worker No. 2	WL2	WL2	-	WL4
Worker No. 3	WL1	WL1	WL1	-
Worker No. 4	WL5	WL5		WL1
Worker No. 5	WL6	-	WL2	WL2
Worker No. 6	-	WL6	WL6	WL6
Worker No. 7	WL4	WL4	WL4	-
Worker No. 8	-	WL3	WL3	WL3

Noise Level of Worker No.1: 89.65
Noise Level of Worker No.2: 89.95
Noise Level of Worker No.3: 89.51
Noise Level of Worker No.4: 89.58
Noise Level of Worker No.5: 89.96
Noise Level of Worker No.6: 89.24
Noise Level of Worker No.7: 89.21
Noise Level of Worker No.8: 89.74

Fig. 6.14 Solution report generated by the *NHP Solution Module* (Case NC-6)

The detailed solution reports of all seven cases are summarized below.

Report 1 (Case NC-1) - Engineering approach, job rotation, and the use of HPDs

Total noise control cost: 28,500 baht

Engineering Approach:

- *Apply NRS technique 1 to machines M4, M5, and M6*

Job Rotation:

- *Implement job rotation using the current workforce (6 workers)*

The Use of HPDs: ---Not required---

Table 6.4 Daily work assignments for Case NC-1

Worker	*Work Period*				*Daily Noise Exposure (dBA)*
	1	*2*	*3*	*4*	
W1	*WL2*	*WL5*	*WL5*	*WL5*	*89.95*
W2	*WL1*	*WL1*	*WL3*	*WL3*	*88.80*
W3	*WL3*	*WL3*	*WL1*	*WL1*	*88.80*
W4	*WL6*	*WL6*	*WL6*	*WL4*	*89.88*
W5	*WL5*	*WL2*	*WL2*	*WL2*	*87.88*
W6	*WL4*	*WL4*	*WL4*	*WL6*	*88.10*

Report 2 (Case NC-2) - Engineering approach and job rotation

Total noise control cost: 28,500 baht

Engineering Approach:

- *Apply NRS technique 1 to machines M4, M5, and M6*

Job Rotation:

- *Implement job rotation using the current workforce (6 workers)*

Table 6.5 Daily work assignments for Case NC-2

Worker	*Work Period*				*Daily Noise Exposure (dBA)*
	1	*2*	*3*	*4*	
W1	*WL2*	*WL5*	*WL5*	*WL5*	*89.95*
W2	*WL1*	*WL1*	*WL3*	*WL3*	*88.80*
W3	*WL3*	*WL3*	*WL1*	*WL1*	*88.80*
W4	*WL6*	*WL6*	*WL6*	*WL4*	*89.88*
W5	*WL5*	*WL2*	*WL2*	*WL2*	*87.88*
W6	*WL4*	*WL4*	*WL4*	*WL6*	*88.10*

Report 3 (Case NC-3) - Engineering approach and the use of HPDs

Total noise control cost: 28,800 baht

Engineering Approach:

- *Apply NRS technique 1 to machines M4, M5, and M6*

The Use of HPDs:

- *Enforce the use of Type-A HPD at worker locations WL1, WL5, and WL6*

Table 6.6 Daily work assignments for Case NC-3

Worker	*Work Period*				*Daily Noise Exposure (dBA)*
	1	*2*	*3*	*4*	
W1	*(WL1)*	*(WL1)*	*(WL1)*	*(WL1)*	*82.97*
W2	*WL2*	*WL2*	*WL2*	*WL2*	*86.58*
W3	*WL3*	*WL3*	*WL3*	*WL3*	*85.68*
W4	*WL4*	*WL4*	*WL4*	*WL4*	*87.02*
W5	*(WL5)*	*(WL5)*	*(WL5)*	*(WL5)*	*82.80*
W6	*(WL6)*	*(WL6)*	*(WL6)*	*(WL6)*	*82.62*

Note: Worker locations in parentheses are those where the use of HPDs is required.

Report 4 (Case NC-4) - Job rotation and the use of HPDs

Total noise control cost: 1,000 baht

Job Rotation:

- *Implement job rotation using the current workforce (6 workers)*

The Use of HPDs

- *Enforce the use of Type-B HPD at worker locations WL2 and WL3*

Table 6.7 Daily work assignments for Case NC-4

Worker	*Work Period*				*Daily Noise Exposure (dBA)*
	1	*2*	*3*	*4*	
W1	*WL1*	*WL1*	*(WL3)*	*(WL3)*	*87.87*
W2	*WL5*	*WL5*	*(WL2)*	*WL4*	*89.97*
W3	*WL6*	*(WL3)*	*WL5*	*WL5*	*89.94*
W4	*(WL3)*	*WL6*	*WL6*	*WL6*	*89.71*
W5	*WL4*	*WL4*	*WL4*	*(WL2)*	*89.72*
W6	*(WL2)*	*(WL2)*	*WL1*	*WL1*	*87.97*

Note: Worker locations in parentheses are those where the use of HPDs is required.

Report 5 (Case NC-5) - Engineering approach

Total noise control cost: 28,500 baht

Engineering Approach:

- *Apply NRS technique 1 to machines M4, M5, and M6*

Table 6.8 Daily work assignments for Case NC-5

Worker	*Work Period*				*Daily Noise Exposure (dBA)*
	1	*2*	*3*	*4*	
W1	*WL1*	*WL1*	*WL1*	*WL1*	**90.97**
W2	*WL2*	*WL2*	*WL2*	*WL2*	*86.58*
W3	*WL3*	*WL3*	*WL3*	*WL3*	*85.68*
W4	*WL4*	*WL4*	*WL4*	*WL4*	*87.02*
W5	*WL5*	*WL5*	*WL5*	*WL5*	**90.80**
W6	*WL6*	*WL6*	*WL6*	*WL6*	**90.62**

It is seen that workers W1, W5, and W6 receive the daily noise exposure that exceeds 90 dBA. Therefore, the NHP program recommends that management increase the noise control budget to 39,500 baht. The revised report is shown as follows:

Total noise control cost: 39,500 baht

Engineering Approach:

- *Apply NRS technique 1 to machines M1, M4, and M5*
- *Apply NRS technique 2 to machine M6*

Table 6.9 Recommended daily work assignments for Case NC-5

Worker	*Work Period*				*Daily Noise Exposure (dBA)*
	1	*2*	*3*	*4*	
W1	*WL1*	*WL1*	*WL1*	*WL1*	*84.12*
W2	*WL2*	*WL2*	*WL2*	*WL2*	*85.86*
W3	*WL3*	*WL3*	*WL3*	*WL3*	*85.13*
W4	*WL4*	*WL4*	*WL4*	*WL4*	*89.28*
W5	*WL5*	*WL5*	*WL5*	*WL5*	*86.26*
W6	*WL6*	*WL6*	*WL6*	*WL6*	*89.98*

Report 6 (Case NC-6) - Job rotation with additional workers

Total noise control cost: ---Not required---

Job Rotation:

- *Implement job rotation using all 8 workers*

Table 6.10 Daily work assignments for Case NC-6

Worker	*Work Period*				*Daily Noise Exposure (dBA)*
	1	*2*	*3*	*4*	
W1	*WL3*	-	*WL5*	*WL5*	*89.65*
W2	*WL2*	*WL2*	-	*WL4*	*89.95*
W3	*WL1*	*WL1*	*WL1*	-	*89.51*
W4	*WL5*	*WL5*	-	*WL1*	*89.58*
W5	*WL6*	-	*WL2*	*WL2*	*89.96*
W6	-	*WL6*	*WL6*	*WL6*	*89.24*
W7	*WL4*	*WL4*	*WL4*	-	*89.21*
W8	-	*WL3*	*WL3*	*WL3*	*89.74*

Report 7 (Case NC-7) - The use of HPDs

Total noise control cost: 600 baht

The Use of HPDs:

- *Enforce the use of Type-A HPD at all six worker locations*

Table 6.11 Daily work assignments for Case NC-7

Worker	*Work Period*				*Daily Noise Exposure (dBA)*
	1	*2*	*3*	*4*	
W1	*(WL1)*	*(WL1)*	*(WL1)*	*(WL1)*	*83.59*
W2	*(WL2)*	*(WL2)*	*(WL2)*	*(WL2)*	*84.37*
W3	*(WL3)*	*(WL3)*	*(WL3)*	*(WL3)*	*83.82*
W4	*(WL4)*	*(WL4)*	*(WL4)*	*(WL4)*	*83.29*
W5	*(WL5)*	*(WL5)*	*(WL5)*	*(WL5)*	*83.68*
W6	*(WL6)*	*(WL6)*	*(WL6)*	*(WL6)*	*83.31*

Note: Worker locations in parentheses are those where the use of HPDs is required.