5.2.1.2 Plant Location

The plant is located about 4 kilometers from the asphalt paving site, between the ring road and the terminal building 3 of the Cairo International Airport as shown in map in figure (5.4).

Figure 5.4 the New Runway Project (Cairo International Airport) map

The plant is about 8 kilometers from any residential area in the region as the environment ministry doesn't allow the construction of asphalt mixing plants near crowded or residential areas.

5.2.1.3 Plant Classification

The plant is classified as a batch mix plant as the aggregate is dried first, then transferred to a mixer where it is mixed with the liquid asphalt.

The plant consists of:

- Areas for aggregate storage.
- Silos for fine aggregate storage.
- Bitumen tanks for bitumen storage and heating.
- Cold aggregate bins.
- Conveyors for aggregate movement.
- Rotary Aggregate Dryer.
- Hydraulic Elevator to move aggregate to top of mixer.
- Screens and Bins.
- The mixer.
- Control Cabin.

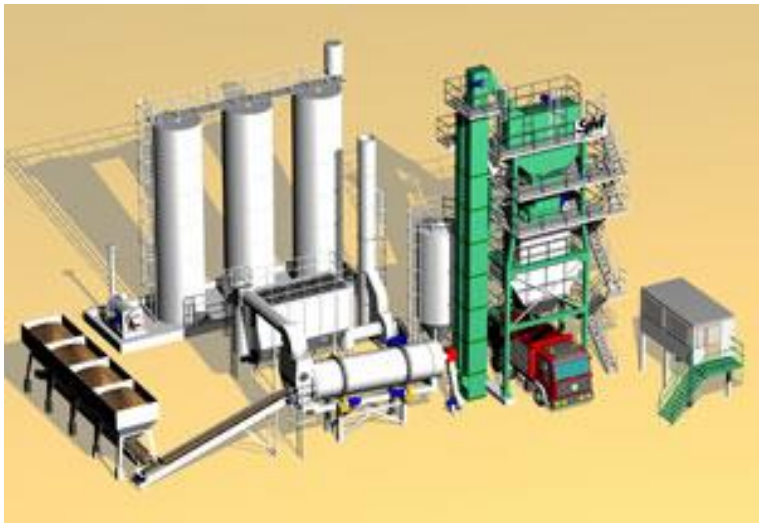


Figure 5.5 Batch Mix Asphalt Plant

5.2.1.4 Asphalt Mixing Plant Operation

Aggregate is stored at the particular storage areas then lifted to the cold aggregate bins using a loader, and then aggregate is moved by conveyors to the rotary aggregate dryer then elevated to the asphalt mixer.

Bitumen is stored in particular tanks then heated and elevated to be mixed with fine and coarse aggregates at 150 degree Celsius to form HMA.

5.2.1.5 Environmental Remarks and Concerns

- Dust: One clear problem in asphalt mixing plant sites is dust, it was observed that when the plant is working, dust covers all the asphalt plant area making it almost impossible even to see the plant.
- Temperature: the increase in temperature in the mixing plant area is also a problem. It occurs due to the dust emission and due to the exhaust out of bitumen heaters, aggregate dryer and the mixing operation itself.
- Gaseous Emissions: This is one of the dangerous environmental problems in asphalt mixing plants, gases such as carbon dioxide, carbon monoxide and others are emitted into air due to the high temperature of asphalt mixing and bitumen heating.
- Workers Health: this is one site workers wouldn’t like to be in, difficulty in breathing, eye irritation and exhaustion are the most common complaints from workers in this asphalt mixing site
- Impact on Surrounding Environment: as concluded from previous problems it is clear that asphalt mixing plants should be far away from any residential or even just crowded areas as effects of dust and other emissions may be fatal.
- Other concerns like noise, workers safety, fuel usage and global warming should also be taken into consideration.

5.2.2 HMA Transportation

Hot mix asphalt is then transported using dump trucks to the pavement construction site. It takes around 15 minutes to get to the site, the dump trucks do not cross residential areas as the plant is close to the site and there is a road constructed by the contractor for the trucks to pass through.

5.2.3 HMA Placing in Site

Before the arrival of HMA to site the surface of the base course layer should be cleaned of all foreign materials and mechanically broomed to remove any irregularities and coarse dust, after that prime coat should be applied to the finished surface. HMA arrives to the construction site then its temperature is measured to assure it is above 140 degrees Celsius as mentioned in the project specifications then the dump truck dumps the HMA into a finisher as seen in figure (5.6), the finisher moves and spreads the HMA according to the required thickness with the help of automatic sensors and skilled labor men.

Figure 5.6 Asphalt Finisher

HMA is then compacted using specialized roller compactors as shown in figure (5.7).

Figure 5.7 Roller Compactor

5.2.3.1 Environmental Remarks and Concerns

- Temperature: the increase in ambient temperature due to the high temperature of the HMA could be unbearable, especially in the summer days.
- Gaseous Emissions: this is the worst place in the case of exposure to gaseous emissions. Labor and engineers standing near finishers are exposed to these emissions which causes many complaints among them.
- Workers Health: Labor men working in the site are exposed to very high temperatures for long times, the workers complained that sometimes working for 12 continuous hours in that high temperature causes them psychological disturbances, also emissions from the HMA causes difficulty in breathing, eye irritation and other serious disease.
- Other concerns also were observed such as the impact on surrounding environment, dust and workers safety.

5.3 Cairo Suez Road Maintenance Project

The project includes the expansion and maintenance of 8 kilometers of the eastern entrance of Cairo from Cairo Suez Road as shown in map figure (5.8).

Owner: Egyptian Authority of Roads and Bridges

Contractor: Arab Contractors

Consultant/Engineer: ACE Moharram Bakhoum

Figure 5.8 Cairo Suez Road Maintenance Project map

5.3.1 Asphalt Mixing Plant

Type: SIM Automatic Plant.

Origin: Italy

Capacity: 260 Ton/Hour

5.3.1.1 Asphalt Plant Location

The plant is located near the region of Kattameya within a group of asphalt plants owned by different companies; the plant is around 20 kilometers away from the paving construction site. The exact location of the plant is as shown in the map in figure (5.9).

Figure 5.8 Kattameya Asphalt Mixing Plant Map

5.2.1.2 Plant Classification

The plant is classified as a batch mix plant as the aggregate is dried first, then transferred to a mixer where it is mixed with the liquid asphalt.

The main constituents of the plant are the same as the previous plant as both plants are batch mix plants. Some pictures of the plant are shown in the figures (5.10,5.11,5.12,5.13).

Figure 5.10 Kattameya Asphalt Mixing Plant (1)

Figure 5.11 Kattameya Asphalt Mixing Plant (2)

Figure 5.12 Kattameya Asphalt Mixing Plant (3)

Figure 5.13 Kattameya Asphalt Mixing Plant (4)

5.3.1.3 Asphalt Mixing Plant Operation

The mixing operation is exactly like the previous plant as both are batch mix plants and have the same type, but the only difference between both plants is the capacity.

5.3.1.4 Environmental Remarks and Concerns

- Dust: One clear problem in asphalt mixing plant sites is dust, it was observed that when the plant is working, dust covers all the asphalt plant but as this plant is newer than the previous plant dust emissions are obviously less.
- Temperature: the increase in temperature in the mixing plant area is also a problem, it occurs due to the dust emission and due to the exhaust out of bitumen heaters, aggregate dryer and the mixing operation itself.
- Gaseous Emissions: This is one of the dangerous environmental problems in asphalt mixing plants, gases such as carbon dioxide, carbon monoxide and others are emitted into air due to the high temperature of asphalt mixing and bitumen heating.
- Workers Health: this is one site workers wouldn't like to be in, difficulty in breathing, eye irritation and exhaustion are the most common complaints from workers in this asphalt mixing site
- Impact on Surrounding Environment: as concluded from previous problems it is clear that asphalt mixing plants should be far away from any residential or even just crowded areas as effects of dust and other emissions may be fatal.
- Other concerns like noise, workers safety, fuel usage and global warming should also be taken into consideration.

5.3.2 HMA Transportation

In this case the hauling distance is relatively greater than the previous case as the dump truck has to travel 20 kilometers from the plant to the site; Dump trucks also pass through residential areas and it was clear that the HMA on the trucks was not covered as shown in figure (5.14,5.15) which caused dripping of asphalt from the truck.

Figure 5.14 Uncovered asphalt dump trucks

Figure 5.15 Uncovered asphalt dump trucks (2)

5.3.3 HMA Placing in Site

It was clear that the quality of executed work is relatively lower than the previous project. The surface of the base coarse layer wasn't properly cleaned before applying prime coat. At the arrival of the HMA, the temperature wasn't measured before placing asphalt. The following figures (5.16,5.17) illustrate the placing execution.

Figure 5.16 Placing of HMA by day

Figure 5.17 Placing of HMA by night

5.3.3.1 Environmental Remarks and Concerns

- Temperature: the increase in temperature due to the high temperature of the HMA could be unbearable, especially in the summer days.
- Gaseous Emissions: this is the worst place in the case of exposure to gaseous emissions labor and engineers standing near finishers are exposed to these emissions which causes many complaints among them.
- Workers Health: Labor men working in the site are exposed to very high temperatures for long times, one of the workers complained that sometimes he works for 12 continuous hours in that high temperature which causes him psychological disturbances, also emissions from the HMA causes difficulty in breathing, eye irritation and other serious disease.
- Other concerns also were observed such as the impact on surrounding environment, dust and workers safety.

5.4 Field Research Conclusions

After visiting two HMA plants and two HMA paving sites it was clear that there are many environmental remarks and concerns, different concerns were mentioned in this chapter. It is difficult for an individual to evaluate such concerns; professional opinion is needed for evaluation.

5.5 Survey

In order to evaluate the Environmental Impact of HMA and the WMA's in a real market environment, a survey was conducted among professionals in the paving industry in Egypt. The survey consisted of 10 questions which were either generally about current paving practices in Egypt or about WMA and the respondent's opinion on its potential.

5.5.1 Sample Size

Information about the total population of professionals working in the asphalt paving industry in Egypt is hard to acquire, therefor the standard statistical formula (Equation 5.1) **(T.P. Hutchinson, 1993)** [26] which does not require the population size was used to determine the sample size in this survey.

$$ss = \frac{Z^2 * (p) * (1-p)}{c^2} \quad \text{..... Equation 5.1}$$

Where:

Z = Z value (e.g. 1.96 for 95% confidence level)
p = percentage picking a choice, expressed as decimal
(.5 used for sample size needed)
c = confidence interval, expressed as decimal
(e.g.,0.2 = ± 20%)

For 95% confidence level and a confidence interval of ± (12% to 15%) a sample size is calculated as follows:

$$ss = \frac{1.96^2 * (0.5) * (1-0.5)}{0.135^2} = 52$$

A sample size of 42 to 66 samples was calculated. In total 52 responses were received from the 60 questionnaires that were sent out to professionals from various sectors of the paving industry. The breakdown of the respondents between sectors is as follows:

- 6 Engineers from private and public **Owner** firms.
- 21 Engineers from private **Consultant** firms.
- 25 Engineers from private and public **Contractor** firms.

It must be noted that all the respondents participated in this study as individuals and therefore their answers do not represent their companies' opinions in any way. Their professional positions are only mentioned to try to evaluate how various issues related to Asphalt Mixing may appear differently to different sectors within the paving industry.

By choosing participants from the various sectors of the industry, the results give a good overall idea about the Environmental Impact of Asphalt Paving and the WMA's potential and people's main concerns regarding WMA in Egypt.
The complete list of questions as delivered to the respondents and a summary about the research that was sent with it are showed in appendix (A) and the answers from all respondents, translated from Arabic as directly as possible are as follows.

5.5.2 Survey Results

Following are summaries of the responses for each of the 10 questions. The surveys were conducted in Arabic and therefore all questions and answers are translated.

Question 1: The following are the main steps of the asphalt paving industry in Egypt, According to your opinion please evaluate the environmental impact of each step as follows:

1. **High Impact**
2. **Medium Impact**
3. **Low Impact**

Asphalt Mixing (Plant)	Asphalt Mix Transportation	Asphalt Placing

3 points were given for the high impact, 2 points for the medium impact and 1 point for the low impact.

- The asphalt mixing stage had the lead with 140 points.
- The asphalt placing stage came after the mixing stage with 111 points.
- The asphalt mix transportation stage came last with 80 points.

Question 2: The following are some of the environmental impacts that can be taken into consideration while studying the environmental impact of the asphalt paving industry; please evaluate those impacts as follows:

- **No Impact = 1 Point**
- **Low Impact = 2 Points**
- **Medium Impact = 3 Points**
- **High Impact = 4 Points**
- **Very High Impact = 5 Points**

- **Asphalt Mixing (Plant) Stage**

Environmental Impact	**Final Result**
Dust	**227**
Temperature Emissions	**178**
Gaseous Emissions	**177**
Workers Health	**200**
Impact on Surrounding Environment	**197**
Other (…….)	**Noise**

- **Asphalt Mix Transportation Stage**

Environmental Impact	**Final Result**
Temperature Emissions	**122**
Gaseous Emissions	**119**
Other (…….)	**Dripping**

- **Asphalt Placing Stage**

Environmental Impact	**Final Result**
Dust	**137**
Temperature Emissions	**163**
Gaseous Emissions	**168**
Workers Health	**230**
Impact on Surrounding Environment	**145**
Other (…….)	

- As for the asphalt mixing stage the highest impact was for dust produced by the asphalt mixing plant which scored 227 points, workers health and the impact on surrounding environment came second and third simultaneously, 15 professionals added noise to be another impact that should be taken into consideration during the asphalt mixing stage.

- As for the asphalt mix transportation stage temperature emissions had a slighter lead on the gaseous emissions but both had an overall low point score as the professionals see this stage to be of low impact as mentioned in the results of question 1, 6 professionals added asphalt mix dripping from transportation trucks as another impact that should be taken into consideration during asphalt mix transportation stage.
- As for the asphalt placing stage the highest impact was for workers' health which scored the highest between impacts of all stages with 230 points, gaseous emissions and temperature emissions came second and third simultaneously.

Question 3: In your opinion, what is the effect of high temperature of the asphalt mix on the daily production rate in the site?

- ☐ **Production Rate Decreases**
- ☐ **No effect on Production Rate**

- 42 Professionals (80%) agreed that high temperatures of the asphalt mix decrease the daily production rate in the site and that any decrease in this temperature would obviously increase the daily production rate.

- 10 Professionals (20%) agreed that a high temperature of the asphalt mix has no effect on the daily production rate.

Question 4: Are there any clear environmental protection plans included in projects specifications that the contractors should stick to during projects execution?

- ☐ **Yes.**
- ☐ **No.**
- ☐ **I don't know.**

- 29 Professionals (55%) answered **No** to this question as they have never seen before such a plan included in any project specs they have ever worked in before.

- 18 Professionals (35%) answered **Yes** to this question as they experienced some projects with such plans that should be submitted by the consultant before project execution.
- 5 Professionals (10%) answered **I don't know** to this question.

Question 5: Have you received any health or psychological complaints due to the high temperatures and gaseous emissions of the asphalt mix?

☐ **Yes.**

☐ **No.**

- 42 Professionals (80%) answered **Yes** to this question.
- 10 Professionals (20%) answered **No** to this question.

Question 6: What are the most common diseases that you realized among workers in this industry?

- Disease mentioned by the industry professionals were :
    - Respiratory Tracts
    - Skin Cancer
    - Bronchitis
    - Irritation of Eyes
    - Lung Cancer
    - Bone Pain
    - Asthma
    - Skin Burning
    - Heart Disease
    - Psychological disorders
    - Different sexual disease

Question 7: Have you received any complaints from non-participants in the asphalt paving projects (residents of nearby areas ,….. etc.)?

- ☐ **Yes. (Complaints:……..)**
- ☐ **No.**

- 27 Professionals (52%) answered **Yes** to this question as they experienced some complaints such as: (dust, gaseous emissions, temperature increase, noise).
- 25 Professionals (48%) answered **No** to this question as they did not experience any complaints before.

Question 8: Have you ever heard of methods to mix HMA at lower temperatures?

- ☐ **Yes. (Methods:……)**
- ☐ **No.**

- 32 Professionals (62%) answered **No** to this question as they have never heard before of other methods.
- 20 Professionals (38%) answered **Yes** to this question as they have heard of other methods such as: (Cold Mix and Warm Mix).

Question 9: If there was another method to mix asphalt and place it with the same quality at lower temperatures which will lead to a decrease in emissions but with an increase in cost (from 3% to 7%), would you recommend using it?

- ☐ **Yes. (Conditions:……..)**
- ☐ **No.**

- 47 Professionals (90%) answered **Yes** to this question as they see it will be more environmental friendly, increase production rate and better for workers health, but they had some conditions such as
    - Quality Preservation
    - Additives Produced in Egypt
    - Competitive Price
    - The method should be in the specifications of the project

- 5 Professionals (10%) answered **No** to this question as they see that the HMA method is the best there is and it has great advantages as it is well known and popular and workers have been familiar with it.

Question 10: How do you regard the way that the Egyptian government deals with the environmental problems resulting from the HMA production?

- ☐ **Serious**
- ☐ **Not Serious**

- 42 Professionals (80%) said that the government is **Not Serious** when dealing with the problems resulting from the environmental impact of asphalt paving stages.
- 10 Professionals (20%) said that the government is **Serious** when dealing with the problems resulting from the environmental impact of asphalt paving stages.

5.5.3 Survey Discussion

- Professionals consider the asphalt mixing stage as the stage of worst impact on environment; Dust is the worst of all impacts during asphalt mixing as mentioned in the previous chapter, sometimes workers cannot see the asphalt plant during mixing because of dust. Workers health and the surrounding environment are also of bad environmental impact as emissions including gases and dust cause discomfort and disease.
- Transportation stage had the least impact as professionals regard it as a transitional stage and no workers are exposed to the asphalt mix during this stage.
- Asphalt placing stage is considered of bad environmental impact; Workers health in particular was the greatest concern for all professionals because workers in the pavement construction site are directly exposed to HMA, temperature and gaseous emissions are also of bad environmental impact as mentioned by professionals.
- The majority of professionals considered that the high temperature of asphalt decrease the production rate and that any decrease in mixing and placing temperatures would improve the daily production rate of paving specially that there are no methods to protect workers from such high temperatures.

- A slight majority of professionals agreed that there are no environmental plans implemented in asphalt paving projects. It is clear that in third world countries like Egypt environmental plans are not important enough to be implemented in asphalt paving projects.
- 80% of professionals have experienced different health complaints from workers due to high temperatures and high rate of emissions of the HMA.
- Many health complaints were referred to by professionals and many diseases were found among the workers in this industry. The most dangerous diseases mentioned in the survey were respiratory tracts, cancer, heart disease and sexual disease.

- 62% of professionals never heard before of different methods to mix asphalt rather than the regular HMA. Also 38% of professionals mentioned some other methods like cold mix asphalt which they commented that it is much more expensive and impractical for large projects. Two academic teachers mentioned the WMA method and said that they are performing studies on it to check its quality and performance.

- The majority of professionals agreed to use any other method which would decrease the temperature and emissions even with an increase in cost. They also stated some conditions such as quality preservation, additives produced in Egypt, competitive price and that the method should be in the specifications of the project.

- 80% of survey participants agreed that the Egyptian government does not even care about environmental problems when it comes to asphalt paving projects.

- This survey concluded that the majority of project participants in asphalt paving projects are aware of its environmental issues, it is also clear that there is very little research for new methods to improve this environmental impact, and there is nothing done to protect workers from the dangers of this impact.

5.5.4 Survey Analysis

- From the **Client** representatives' (6 Participants) point of view the scores were as follows:

  - **Asphalt Mixing (Plant) Stage**

Environmental Impact	**Final Result**
Dust	**24**
Temperature Emissions	**22**
Gaseous Emissions	**23**
Workers Health	**22**
Impact on Surrounding Environment	**22**
Other (…….)	

  - **Asphalt Mix Transportation Stage**

Environmental Impact	**Final Result**
Temperature Emissions	**15**
Gaseous Emissions	**14**
Other (…….)	

  - **Asphalt Placing Stage**

Environmental Impact	**Final Result**
Dust	**19**
Temperature Emissions	**17**
Gaseous Emissions	**21**
Workers Health	**25**
Impact on Surrounding Environment	**19**
Other (…….)	

- From the **Consultants** representatives' (21 participants) point of view the scores were as follows:

  - **Asphalt Mixing (Plant) Stage**

Environmental Impact	**Final Result**
Dust	**96**
Temperature Emissions	**72**
Gaseous Emissions	**66**
Workers Health	**80**
Impact on Surrounding Environment	**82**
Other (…….)	**Noise**

  - **Asphalt Mix Transportation Stage**

Environmental Impact	**Final Result**
Temperature Emissions	**54**
Gaseous Emissions	**53**
Other (…….)	**Dripping**

  - **Asphalt Placing Stage**

Environmental Impact	**Final Result**
Dust	**58**
Temperature Emissions	**66**
Gaseous Emissions	**66**
Workers Health	**94**
Impact on Surrounding Environment	**68**
Other (…….)	

- From the **Contractors** representatives' (25 participants) point of view the scores were as follows:

  - **Asphalt Mixing (Plant) Stage**

Environmental Impact	**Final Result**
Dust	**107**
Temperature Emissions	**84**
Gaseous Emissions	**88**
Workers Health	**98**
Impact on Surrounding Environment	**93**
Other (…….)	**Noise**

  - **Asphalt Mix Transportation Stage**

Environmental Impact	**Final Result**
Temperature Emissions	**53**
Gaseous Emissions	**52**
Other (…….)	**Dripping**

  - **Asphalt Placing Stage**

Environmental Impact	**Final Result**
Dust	**60**
Temperature Emissions	**80**
Gaseous Emissions	**81**
Workers Health	**111**
Impact on Surrounding Environment	**59**
Other (…….)	

5.5.4.1 Survey Analysis Remarks

- It is clear that all project participants have similar opinions about environmental impacts, rankings of all impacts for different project participants (Client, Consultant, and Contractor) are almost the same.
- Different project participants agree that workers health during the placing stage is the greatest concern of all concerns mentioned in the survey.
- Dust during the mixing stage was considered the second of all concerns as agreed by different participants.
- It is also clear that all project participants in Egypt are aware of the environmental impact of asphalt pavement construction as they all have similar opinions about different impacts at different stages of the construction.

CHAPTER (6)

RESULTS & ANALYSIS

6.1 Introduction

This chapter describes some of the simplest techniques and methods for impact analysis, and gives information to help choose the most appropriate method for a given situation. Most methods and techniques for identifying, measuring, and assessing impacts rely on expert judgment.

In fact, many checklists, matrices, and models used in EIA represent decades of experience accumulated by numerous experts. The experts themselves are heavily involved in all aspects of the assessment. They are used to help identify the potential for significant impacts, plan data collection and monitoring programs, provide their judgment on the level of significance for specific impacts, and suggest ways of reducing or preventing impacts.

6.2 Choosing a Method

Analysis methods range from simple to complex, requiring different kinds of data, different data formats, and varying levels of expertise and technological sophistication for their interpretation. The analyses they produce have differing levels of precision and certainty. All of these factors should be considered when selecting a method.

The analysis practitioner is faced with a vast quantity of raw and usually unorganized information that must be collected and analyzed in preparation of an EIA report. The best methods are able to:

- Organize a large mass of heterogeneous data;
- Allow summarization of data;
- Aggregate the data into smaller sets with least loss of information; and
- Display the raw data and the derived information in a direct and relevant fashion.

Whatever methods are chosen, the focus of impact assessment has evolved from generating a list of potential impacts on selected environmental components. Today's methods consider the environment to be a dynamic, integrated group of natural and social systems. Impacts occur over time and space. Some impacts are immediate while others are delayed. Some impacts occur as a direct result of an activity; others occur as secondary or higher order impacts resulting from changes in other environmental components.

Decision making should not be restricted to scientific opinions alone, but should also reflect social and cultural viewpoints. A key role of analysis is to identify and communicate potential impacts to the concerned people and encourage rational discussion.

6.3 Appropriateness of Methods for Developing Countries

No single method will meet all the necessary criteria. The objective is to select an array of methods that collectively will meet assessment needs. Reviewing techniques and methods available, only a few are applicable to developing countries. The latter are described here. Most have been used in developing countries, although not all widely so.

Many argue that developing countries cannot afford to use sophisticated methods because they are too expensive. It is suggested that they will only be used if funding from international assistance agencies (IAA) is available. This is only partly true.

Often the application of the sophisticated methods requires input from international EIA experts. If this is the case, the labor costs associated with a method may make it expensive. There are, however, plenty of examples of EIA practitioners in developing countries using sophisticated mathematical models for air and water quality assessment in the environmental assessment of large energy and infrastructure projects. For example, the National Power Corporation in the Philippines uses air dispersion models for the assessment of environmental effects of thermal generating stations. Similarly, most of the scientific and engineering institutes in the People's Republic of China (PRC) that have Class A licenses for EIA have strong capability in computer modeling for EIA.

6.4 Matrices

Matrix methods identify interactions between various project actions and environmental parameters and components. They incorporate a list of project activities with a checklist of environmental components that might be affected by these activities. A matrix of potential interactions is produced by combining these two lists (placing one on the vertical axis and the other on the horizontal axis). One of the earliest matrix methods was developed by **Leopold et al. (1971)** [28]. In a Leopold matrix and its variants, the columns of the matrix correspond to project actions while the rows represent environmental conditions. The impact associated with the action columns and the environmental condition row is described in terms of its magnitude and significance.

Most matrices were built for specific applications, although the Leopold Matrix itself is quite general. Matrices can be tailor-made to suit the needs of any project that is to be evaluated. However, matrices also have their disadvantages: they tend to overly simplify impact pathways, they do not explicitly represent spatial or temporal considerations, and they do not adequately address synergistic impacts. Matrices require information about both the environmental components and project activities. The cells of the matrix are filled in using subjective (expert) judgment, or by using extensive data bases. There are two general types of matrices:

- Simple interaction matrices.
- Significance or importance-rated matrices.

Simple matrix methods simply identify the potential for interaction. Significance or importance-rated methods require either more extensive data bases or more experience to prepare. Values assigned to each cell in the matrix are based on scores or assigned ratings, not on measurement and experimentation. For example, the significance or importance of impact may be categorized (no impact, insignificant impact, significant impact, or uncertain). Alternatively, it may be assigned a numerical score (for example, 0 is no impact, 10 is maximum impact).

6.4.1 Leopold Matrix

(Leopold et al., 1971) [28]*;* designed a matrix with a hundred specified actions and 88 environmental components. Each action and its potential for impacting each environmental item are considered. The magnitude of the interaction (extensiveness or scale) is described by assigning a value ranging from 1 (for small magnitudes) to 10 (for large magnitudes). The assignment of numerical values is based on an evaluation of available facts and data. Similarly, the scale of importance also ranges from 1 (very low interaction) to 10 (very important interaction). Assignment of numerical values for importance is based on the subjective judgment of the interdisciplinary team working on the EIA study. The matrix approach is reasonably flexible. The total number of specified actions and environmental items may increase or decrease depending on the nature and scope of the study. This is one of the attractive features of the Leopold Matrix.

Technically, the Leopold Matrix approach is a gross screening technique to identify impacts. It is a valuable tool for explaining impacts by presenting a visual display of the impacted items and their causes. Summing the rows and columns that are designated as having interactions can provide deeper insight and aid further interpretation of the impacts. The matrix can also be employed to identify impacts during the various parts of the entire project cycle — construction, operation, and even dismantling phases.

- **Is this application appropriate for developing countries?** Yes, but matrices should be specifically developed for application to sector and country conditions. Matrices force EIA practitioners to think systematically about the interactions between project activities and environmental components.

(Lohani and Thanh 1980) [29]**;** used another grading system in which relative weights are assigned to each development activity. If the relative priority of development activity is determined, the total value of a particular activity is the sum of the vertical column represented by that in the matrix, multiplied by the priority value. Finally, the total value of all the interactions is the sum of all horizontal values in the matrix. This method is particularly helpful in identifying major activities and in defining areas where attention is mostly needed in the process of analysis.

6.4.2 Matrix Building

The matrix used is built according to the literature review and the survey results discussed in the previous chapters. As mentioned before the matrix should include the project stages and the environmental impacts affected by these stages.

6.4.2.1 Project Stages

According to the literature preview asphalt paving projects are divided into three main stages.

- HMA Mixing Stage (Plant).
- HMA Transportation Stage.
- HMA Placing Stage.

In the previous chapter professionals were asked to rank the three project stages according to their environmental impact, the HMA mixing stage was considered the most dangerous, the placing and the transportation stage came second and third respectively. These results were taken into consideration when assigning the magnitude and importance scales included in the matrix. The project stages are presented as columns in the matrix.

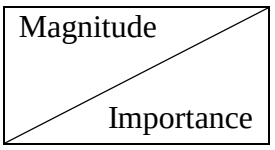
6.4.2.2 Environmental Impacts

Impacts have been discussed through the thesis chapters. The literature review came out with some impacts such as (Workers Health, Gaseous Emissions, etc….), professionals mentioned other impacts and they were mentioned in the survey results such as (Noise, Solid & Hazardous Waste, etc…..). All impacts mentioned before were taken into consideration.
Environmental impacts were divided into categories and subcategories as shown in table (6.1).

Table 6.1 Environmental Impacts Categories

Environmental Impact Category	Atmosphere	Health & Safety	Socio-Economic	Others
Subcategory	Dust	Workers Safety	Economic Impact	Solid & Hazardous Waste
	Temperature Increase	Workers Health	Production Rate	Field Acceptance
	Gaseous Emissions	Public Safety	Workers Support	Fuel and Energy Usage
		Public Health	Public Support	Noise

The environmental impacts are presented as rows in the matrix. The second step in using the Leopold Matrix is to describe the interaction in terms of its magnitude (M) in the upper section and importance (I) in the lower section of each box.



The magnitude of an interaction or impact is represented by numerical scale; it is described by the assignment of a numerical value from one to ten. The value, ten represents the largest magnitude and the value, one represents the lowest magnitude, whereas values near five represent impacts of intermediate magnitude. Assignment of a numerical value for the magnitude of an interaction is related to the extent of any change (for example, if noise levels in a village were expected to increase by 20 dB(A), this is a large increase at night and may score 8 or even 9). The scale of importance also ranges from one to ten. The higher the value, the higher the importance; the lower the value, the lower the importance. Assignment of a numerical value for

importance is based on the subjective judgment of the multi-disciplinary team working on the EIA. Plus (+) or minus (-) can be used to show whether an impact is beneficial or adverse.

6.4.3 Magnitude and Importance Scale Implementation

A. For HMA production

1. **Dust:** One of the most dangerous impacts when it comes to HMA mixing plants is dust; it scored the second high score in the survey as illustrated in the previous chapter. It is also regionally important to get rid of that dust during the mixing stage.
   Therefor dust during mixing stage was given a score of: M= - 9 , I= 9 .
   On the other hand it has almost no impact in the transportation stage and very little impact in the HMA placing Stage.
   Therefor dust during transportation stage was given a score of: M= -1 , I= 1 .
   During placing stage it was given a score of: M= -2 , I= 2 .
2. **Temperature Increase:** It has a moderate impact during the mixing stage as workers are not exposed to asphalt directly while in the placing stage it has a more dangerous impact as workers are exposed directly to asphalt emissions, therefor it is very important to decrease the temperature during the placing stage as asphalt is directly exposed to air, therefor:
   During mixing stage it was given a score of: M= -4 , I= 4 .
   During transportation stage it was given a score of: M= -2 , I= 2 .
   During placing stage it was given a score of: M= -5 , I= 6 .
3. **Gaseous Emissions:** Professionals agreed that it has almost the same magnitude in both the mixing and the placing stage, as for the transportation stage it was almost as dangerous as the temperature increase. As for the importance scale it is relatively more important to get rid of emissions during the placing stage as workers and pedestrians are directly exposed to gaseous emissions, therefor:
   During mixing stage it was given a score of: M= -5 , I= 5 .
   During transportation stage it was given a score of: M= -2 , I= 2 .
   During placing stage it was given a score of: M= -5 , I= 6 .

4. **Noise:** This is one of the impacts added by professionals in the survey as shown in the previous chapter, noise coming out of asphalt plants should be taken into consideration, while in transportation and placing stage in relative to the mixing stage noise has a little impact. As for the importance it is important to decrease the noise during all stages of the project, therefor:

   During mixing stage it was given a score of: M= -7 , I= 4 .

   During transportation stage it was given a score of: M= -2 , I= 4 .

   During placing stage it was given a score of: M= -2 , I= 4 .

5. **Solid and Hazardous Waste:** Waste from mixing stage was mentioned in the literature review, also dripping from HMA trucks during transportation stage was added by professionals as mentioned in the previous chapter, asphalt dripped from trucks is considered as solid waste and also considered when mentioning public health, as for the importance, it has a little importance to prevent the production of solid and hazardous wastes during all stages of the project, therefor:

   During mixing stage it was given a score of: M= -4 , I= 2 .

   During transportation stage it was given a score of: M= -3 , I= 2 .

   During placing stage it was given a score of: M= -2 , I= 2 .

6. **Economic Impact:** This is one of the most important impacts in the field professionals point of view, as contractors will not change a method they are used to and have their workers trained on to use another method that has never been tried in Egypt, therefor:

   During mixing stage it was given a score of: M= +1 , I= 5 .

   During transportation stage it was given a score of: M= +3 , I= 4 .

   During placing stage it was given a score of: M= +2 , I= 4 .

7. **Production Rate:** It is of high importance especially during placing stage, it is also important but relatively less important in the other two stages. As for magnitude asphalt plants work in full capacity and also transportation and placing have positive magnitudes when talking about production rate, therefor:

   During mixing stage it was given a score of: M= +7 , I= 5 .

   During transportation stage it was given a score of: M= +3 , I= 4 .

   During placing stage it was given a score of: M= +2 , I= 6 .

8. **Workers Safety:** It has a high importance scale in all HMA paving stages, although it has a very high magnitude during the placing stage as there are no precautions what so ever applied during this stage in Egypt, lower magnitudes are given for the mixing and transportation stage, therefor:

   During mixing stage it was given a score of: M= -1 , I= 6 .

   During transportation stage it was given a score of: M= -1 , I= 6 .

   During placing stage it was given a score of: M= -7 , I= 6 .

9. **Workers Health:** The most important impacts in all impacts are workers and public health as developing countries spend a great part of their incomes on health preservation and medication, as for the magnitude the survey showed that workers health during the placing stage has the worst impact of all impacts in all stages, also during the mixing stage it had a high magnitude, therefor:

   During mixing stage it was given a score of: M= -8 , I= 9 .

   During transportation stage it was given a score of: M= -1 , I= 9 .

   During placing stage it was given a score of: M= -10 , I= 9 .

10. **Workers Support:** This is one important impact too, as workers' rights are considered very important around the world these days, as for magnitude the workers don't support the mixing stage much as they are always exposed to the dust and other emissions, also during placing stage, therefor:

    During mixing stage it was given a score of: M= -6 , I= 3 .

    During transportation stage it was given a score of: M= -1 , I= 5 .

    During placing stage it was given a score of: M= -8 , I= 6 .

11. **Public Safety:** All projects could use some precautions to prevent public from any accident caused of the project stages; therefor asphalt plants should be far from residential areas and even crowded areas such as marketplaces. Public safety is not affected much by this industry so it has relatively lower magnitudes, therefor:

    During mixing stage it was given a score of: M= -1 , I= 6 .

    During transportation stage it was given a score of: M= -3 , I= 6 .

    During placing stage it was given a score of: M= -2 , I= 6 .

12. **Public Health:** As agreed before workers and public health should be considered of utmost important impacts, therefor public health got a high importance scale but when

considering magnitude the survey showed that the mixing stage has the higher magnitude as it was asked about affecting the surrounding environment, therefor:

During mixing stage it was given a score of: M= -7 , I= 9 .
During transportation stage it was given a score of: M= -2 , I= 9 .
During placing stage it was given a score of: M= -4 , I= 9 .

13. **Public Support:** With the democracy movements in Egypt this impact will soon be of utmost importance meanwhile it still has moderate importance within the public. As for magnitude mixing has the worst public support magnitude as asphalt mixing plants are known for their dangerous emissions, therefor:
    During mixing stage it was given a score of: M= -8 , I= 7 .
    During transportation stage it was given a score of: M= -3 , I= 6 .
    During placing stage it was given a score of: M= -2 , I= 5 .
14. **Field Acceptance:** It is important for people working in the field to accept the method especially during mixing and placing stage. As for magnitude, it is clear that all participants are content with the HMA as no precautions or procedures what so ever are taken to change the mix, therefor:
    During mixing stage it was given a score of: M= +3 , I= 9 .
    During transportation stage it was given a score of: M= +3 , I= 3 .
    During placing stage it was given a score of: M= +3 , I= 9 .
15. **Fuel and Energy Usage:** One of the essential issues rising these days is energy usage as fuel prices are raising and excessive energy usage cause other problems such as (global warming). As for magnitude all production stages have high energy and fuel usage especially the mixing phase, therefor:
    During mixing stage it was given a score of: M= -7 , I= 7 .
    During transportation stage it was given a score of: M= -5 , I= 7 .
    During placing stage it was given a score of: M= -5 , I= 6 .

The matrix for the HMA paving construction is shown in table (6.2) which illustrates the matrix building and the magnitude and importance of each environmental impact.

Table (6.2) Matrix analysis for the environmental impact of HMA paving.

Activity	Asphalt Mixing	Transportation	Site Works
Dust	-9 / 9	-1 / 1	-2 / 2
Temperature Increase	-4 / 4	-2 / 2	-5 / 6
Gaseous Emissions	-5 / 5	-2 / 2	-5 / 6
Noise	-7 / 4	-2 / 1	-2 / 3
Solid & Hazardous Waste	-4 / 2	-3 / 2	-2 / 2
Economic Impact	+1 / 5	+3 / 4	+2 / 4
Production Rate	+7 / 5	+3 / 4	+2 / 6
Workers Safety	-1 / 6	-1 / 6	-7 / 6
Workers Health	-8 / 9	-1 / 9	-10 / 9
Workers Support	-6 / 3	-1 / 5	-8 / 6
Public Safety	-1 / 6	-3 / 6	-2 / 6
Public Health	-7 / 9	-2 / 9	-4 / 9
Public Support	-8 / 7	-3 / 6	-2 / 5
Field Acceptance	+3 / 9	+3 / 3	+3 / 9
Fuel and Energy Usage	-7 / 7	-5 / 7	-5 / 6
Total	-56 / 90	-17 / 67	-47 / 85

B. For WMA Implementation:

1. **Dust:** As mentioned in the literature review using warm mix asphalt would decrease the dust emissions during the mixing stage by an average of 30%, therefor:
   During mixing stage it was given a score of: M= -6
   During transportation stage it was given a score of: M= -1
   During placing stage it was given a score of: M= -2.
2. **Temperature Increase:** As previously mentioned warm mix asphalt could be produced and placed at 35% less temperature than HMA, therefor:
   During mixing stage it was given a score of: M= -2
   During transportation stage it was given a score of: M= -1
   During placing stage it was given a score of: M= -2.
3. **Gaseous Emissions:** 50% reduction in emissions is expected from using WMA as lowering the mixing and placing temperature will reduce the harmful gaseous emissions, therefor:
   During mixing stage it was given a score of: M= -2
   During transportation stage it was given a score of: M= -1
   During placing stage it was given a score of: M= -1.
4. **Noise:** This is one impact that cannot be reduced using WMA, as reducing asphalt temperature has no impact on noise levels, therefor:
   During mixing stage it was given a score of: M= -7
   During transportation stage it was given a score of: M= -2
   During placing stage it was given a score of: M= -2
5. **Solid & Hazardous Waste:** This is another impact that is not affected by temperature reduction, therefor:
   During mixing stage it was given a score of: M= -4
   During transportation stage it was given a score of: M= -3
   During placing stage it was given a score of: M= -2

6. **Economic Impact:** WMA method will affect the cost for the production of asphalt mix, this means that it will reduce the magnitude during the mixing stage but will not affect the other two stages, therefor:
   During mixing stage it was given a score of: M= -1
   During transportation stage it was given a score of: M=+3
   During placing stage it was given a score of: M= +2
7. **Production Rate:** The survey showed that around 80% of professionals consider that HMA high temperature reduces the production rate especially in the placing stage, therefor:
   During mixing stage it was given a score of: M= +8
   During transportation stage it was given a score of: M= +3
   During placing stage it was given a score of: M= +5
8. **Workers Safety:** Usually accidents happen due to labor falling in asphalt mix or prime or tack coat, this is all in the placing stage, therefor:
   During mixing stage it was given a score of: M= -1
   During transportation stage it was given a score of: M= -1
   During placing stage it was given a score of: M= -3.
9. **Workers Health:** Reducing the mixing and placing temperature and emissions will clearly improve the workers' health, therefor:
   During mixing stage it was given a score of: M= -4
   During transportation stage it was given a score of: M= -1
   During placing stage it was given a score of: M= -4
10. **Workers Support:** Workers would support the WMA method as it will improve their health, safety and working conditions, therefor:
    During mixing stage it was given a score of: M= +3
    During transportation stage it was given a score of: M= +3
    During placing stage it was given a score of: M= +3
11. **Public Safety:** This impact will improve slightly specially during placing stage as pedestrians will not be exposed to hot asphalt, therefor:

During mixing stage it was given a score of: M= -1

During transportation stage it was given a score of: M= -3

During placing stage it was given a score of: M= -1.

12. **Public Health:** The reduction of temperature and emissions will improve public health as the public will not be exposed to fumes neither during mixing stage nor during placing stage, therefor:

    During mixing stage it was given a score of: M= -3

    During transportation stage it was given a score of: M= -1

    During placing stage it was given a score of: M= -1.

13. **Public Support:** The public will still have problems with the new method because its environmental impacts were not totally mitigated meanwhile public support will improve especially in the placing stage, therefor:

    During mixing stage it was given a score of: M= -2

    During transportation stage it was given a score of: M= -1

    During placing stage it was given a score of: M= -1.

14. **Field Acceptance:** As mentioned in the survey 90% of professionals are willing to use temperature reduction methods this improves this impact, therefor:

    During mixing stage it was given a score of: M= -2

    During transportation stage it was given a score of: M= -1

    During placing stage it was given a score of: M= -1.

15. **Fuel & Energy Usage:** As mentioned in the literature review the WMA will reduce the energy consumption by an average of 30% during the mixing stage, therefor:

    During mixing stage it was given a score of: M= -4

    During transportation stage it was given a score of: M= -5

    During placing stage it was given a score of: M= -5.

The matrix for the WMA paving construction is shown in table (6.3) which illustrates the matrix building and the magnitude and importance of each environmental impact.

Table (6.3) Matrix analysis for the environmental impact of HMA paving.

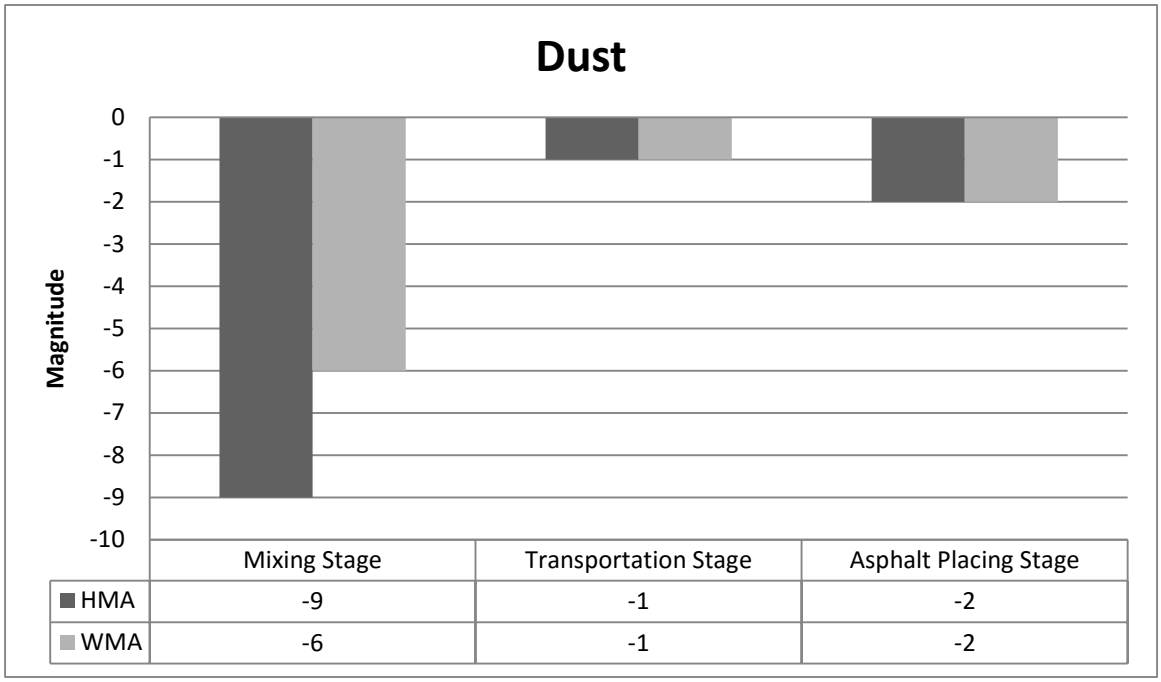
Activity	Asphalt Mixing	Transportation	Site Works
Dust	-6 / 9	-1 / 1	-2 / 2
Temperature Increase	-2 / 4	-1 / 2	-2 / 6
Gaseous Emissions	-2 / 5	-1 / 2	-1 / 6
Noise	-7 / 4	-2 / 1	-2 / 3
Solid & Hazardous Waste	-4 / 2	-3 / 2	-2 / 2
Economic Impact	-1 / 5	+3 / 4	+2 / 4
Production Rate	+8 / 5	+3 / 4	+5 / 6
Workers Safety	-1 / 6	-1 / 6	-3 / 6
Workers Health	-4 / 9	-1 / 9	-4 / 9
Workers Support	+3 / 3	+3 / 5	+3 / 6
Public Safety	-1 / 6	-3 / 6	-1 / 6
Public Health	-3 / 9	-1 / 9	-1 / 9
Public Support	-2 / 7	-3 / 6	+1 / 5
Field Acceptance	+6 / 9	+3 / 3	+6 / 9
Fuel and Energy Usage	-4 / 7	-5 / 7	-5 / 6
Total	-20 / 90	-10 / 67	-6 / 85
Difference %	+64 %	+41 %	+87 %

6.5 Results Discussion:

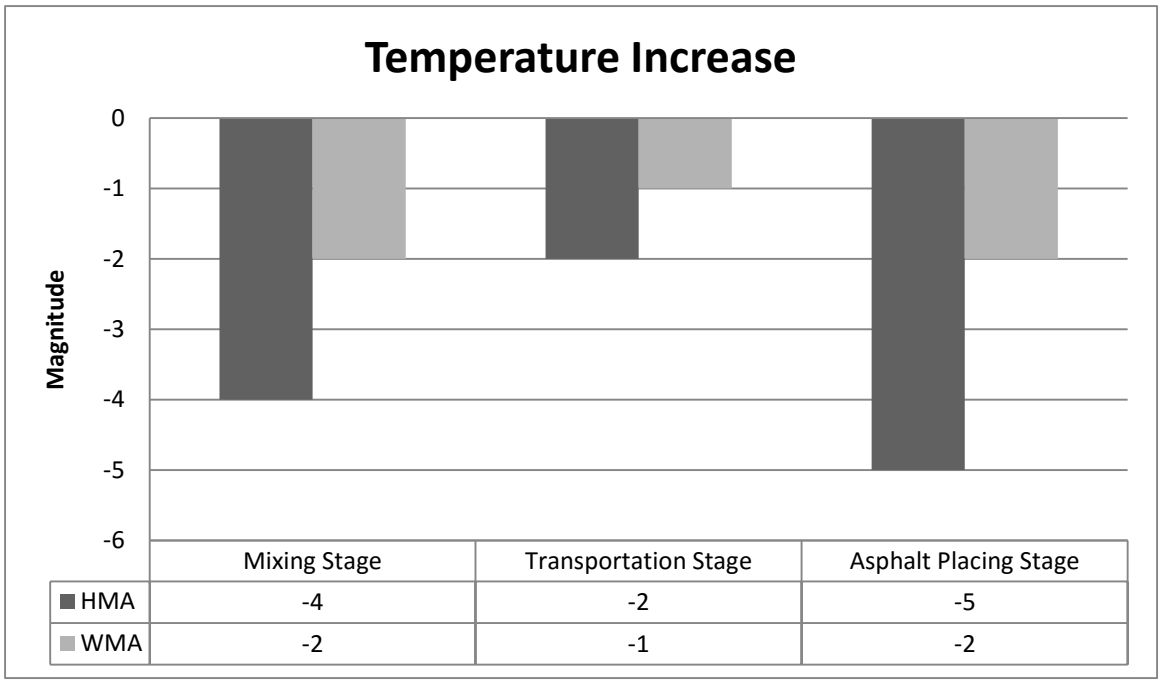
- It is clear that WMA method has a positive impact on almost all environmental issues including the most important (public & workers health) but it also has no impact on other issues (noise – solid & hazardous waste), it also has a negative impact on one issue which is the economic impact although it is slightly negative.
- For the mixing stage, an improvement of 64% on the environmental impact is accompanied with using the WMA method, this is a good improvement but there is still to be done as emissions are not totally cleared, also noise and public health still have negative effects.
- For the transportation stage, an improvement of 41% on the environmental impact is caused by using WMA as public and workers health will improve, although the improvement of the transportation stage is not as clear as other stages because environmental issues accompanied with this stage is not totally related to the asphalt mix.
- The most noticeable improvement is clear in the placing stage, an improvement of 87% on the environmental impact as almost all issues in this stage are affected by the asphalt mix temperatures and emissions. Using WMA will improve the environmental impact clearly as workers and public will not be exposed to high temperatures and emission rates which will improve lots of impacts.
- The best improvements caused by WMA were :
    1. Workers Support
    2. Workers Heath
    3. Public Support
    4. Gaseous Emissions
    5. Public Health

6.6 Analysis and Relationships

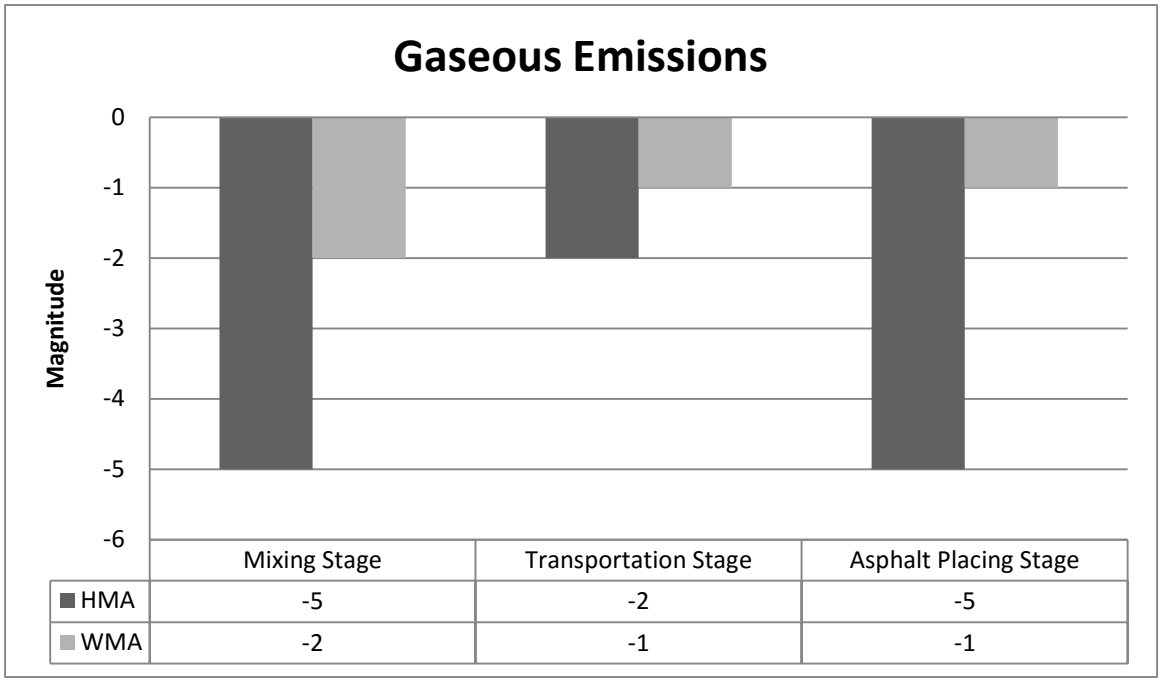
The following bar charts are a graphical presentation for the matrix analysis results comparing the use of HMA and WMA as shown in figures (6.1 to 6.17).



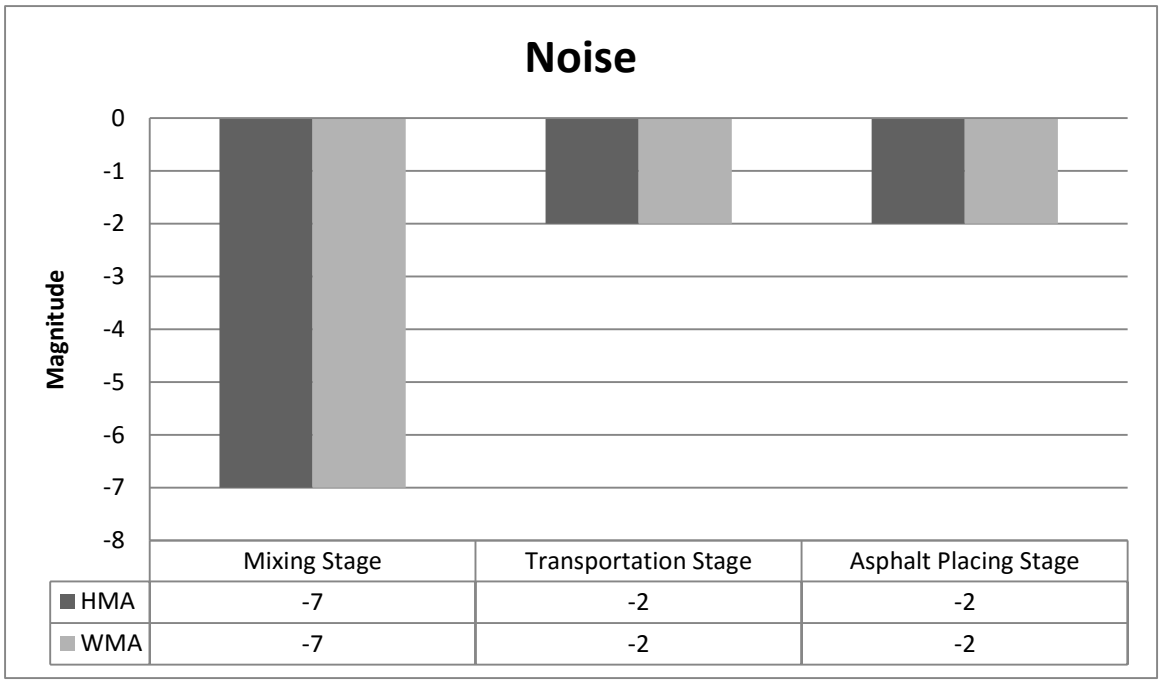
Figure(6.1) Magnitudes of dust impact when using both methods.



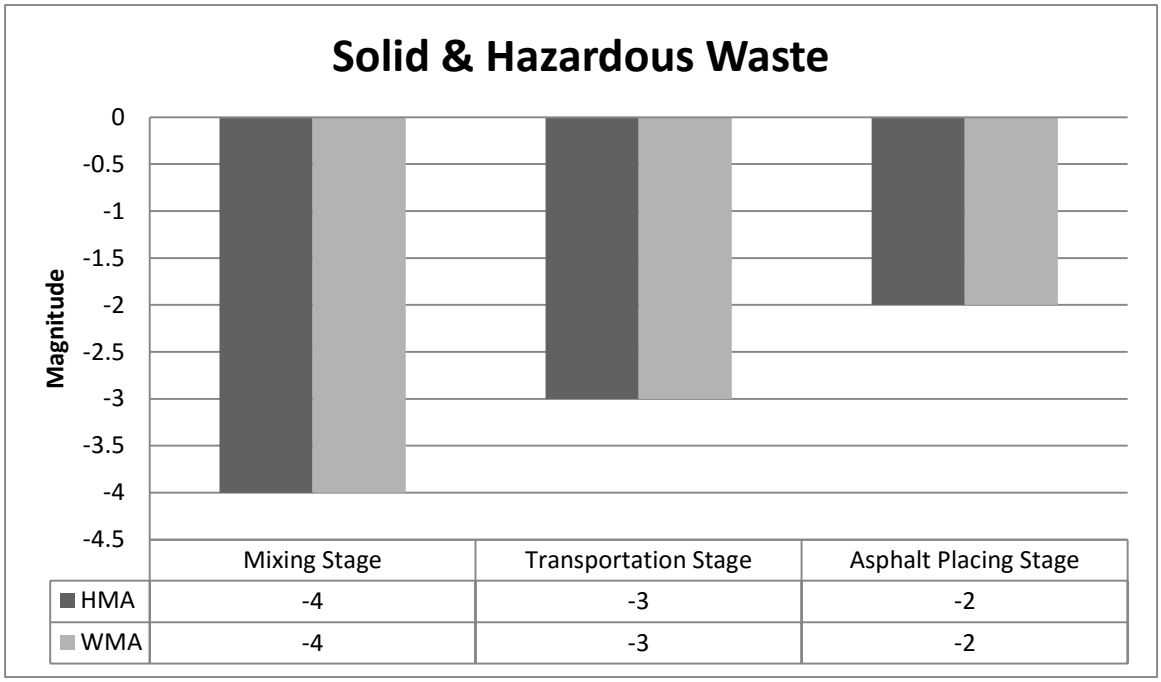
Figure(6.2) Magnitudes of temperature increase impact when using both methods.



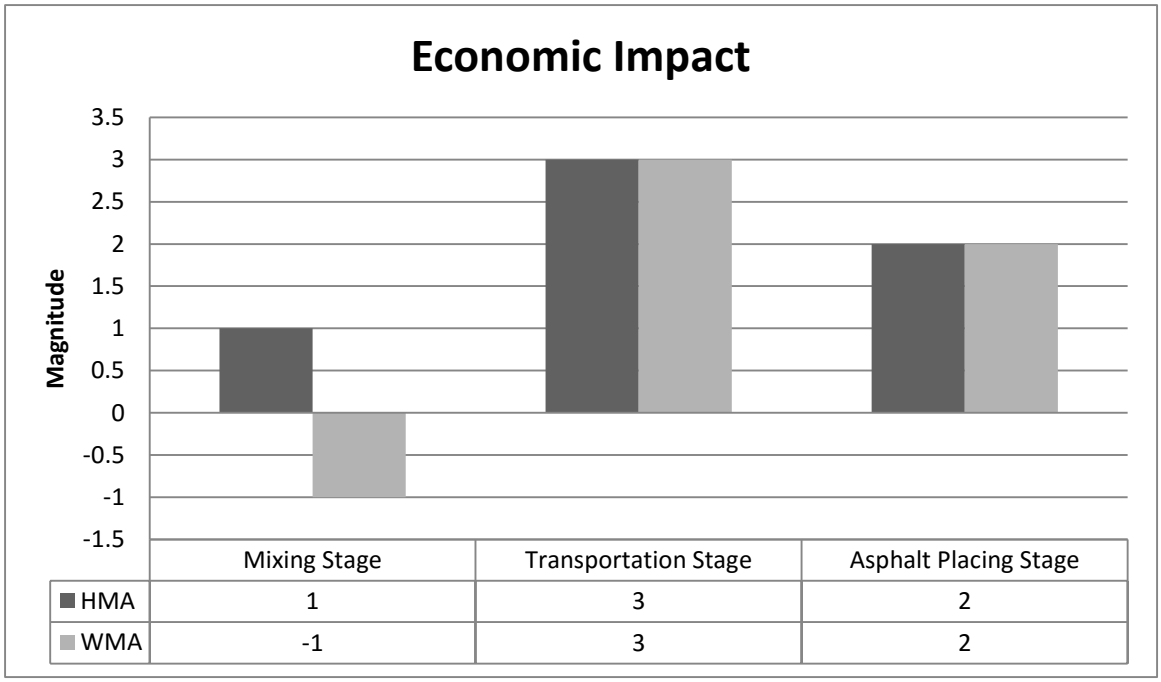
Figure(6.3) Magnitudes of gaseous emissions impact when using both methods.



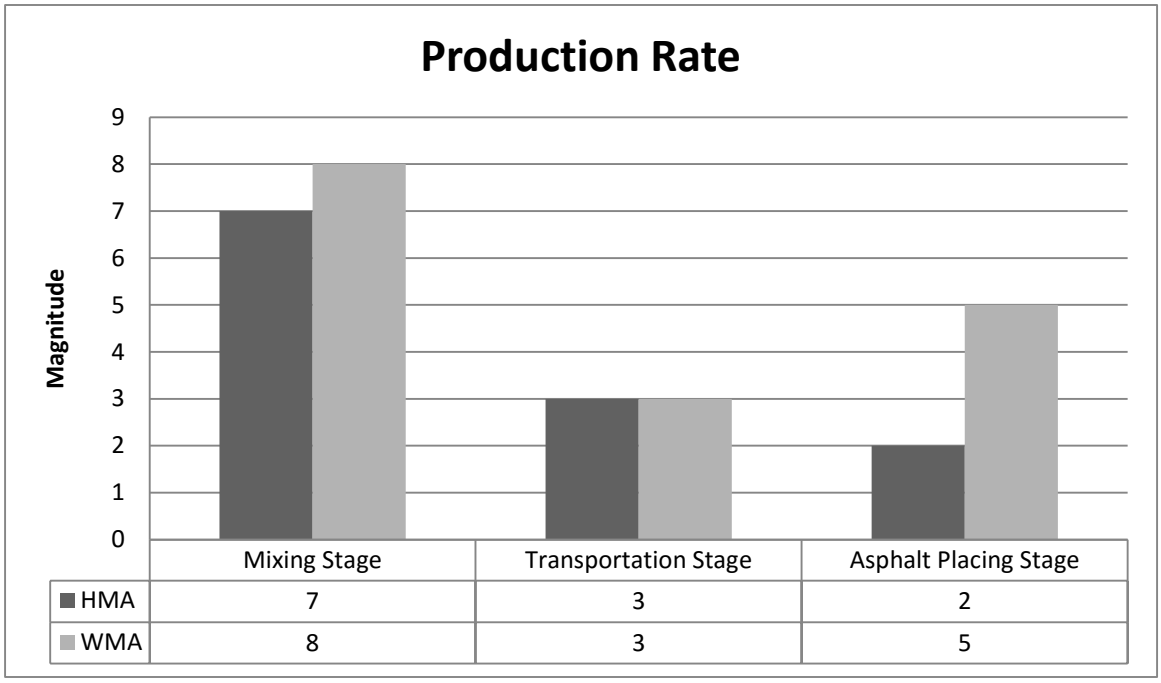
Figure(6.4) Magnitudes of noise impact when using both methods.



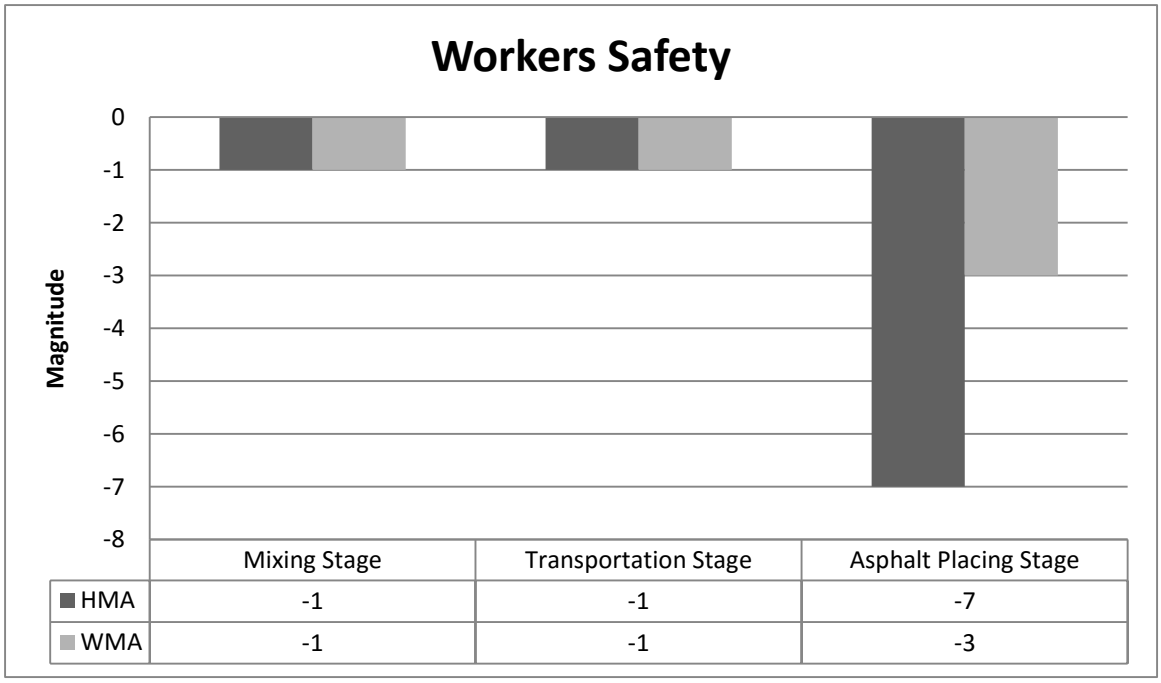
Figure(6.5)Magnitudes of solid and hazardous waste impact when using both methods.



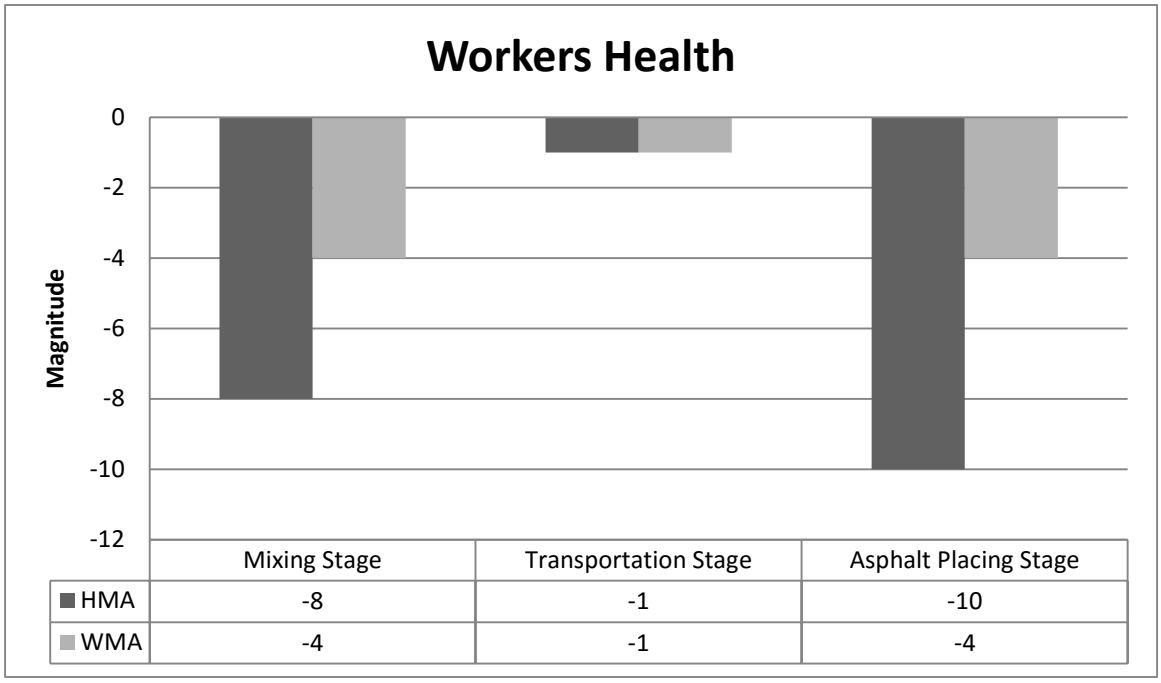
Figure(6.6)Magnitudes of the economic impact when using both methods.



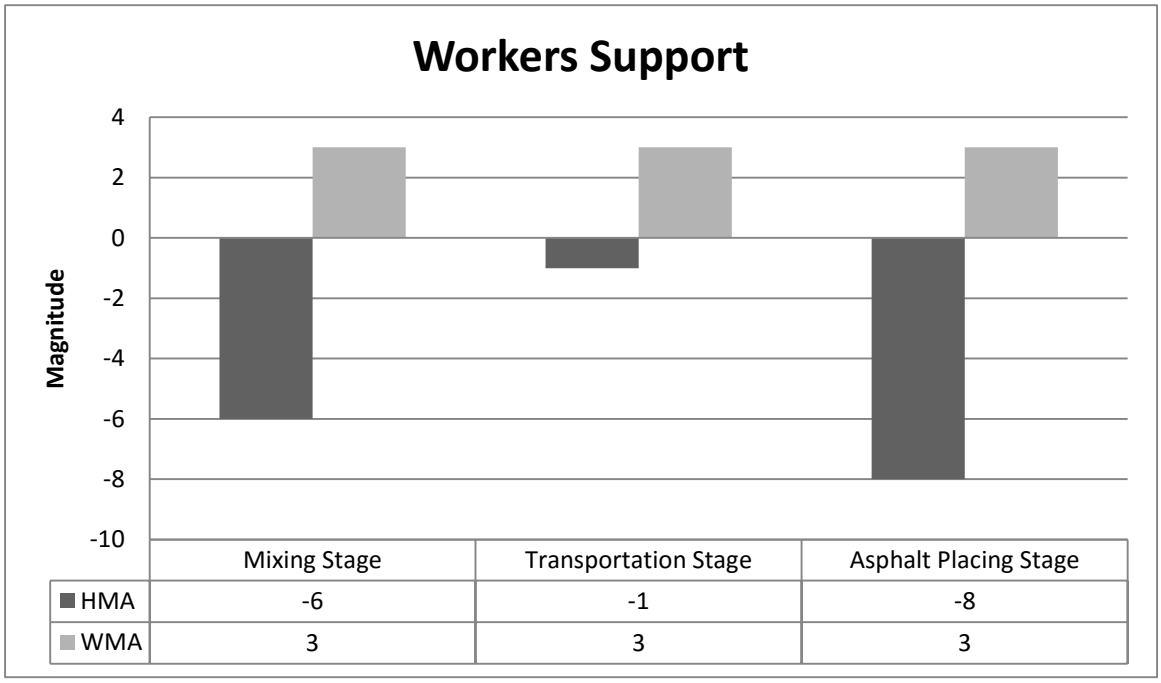
Figure(6.7) Magnitudes of the production rate when using both methods.



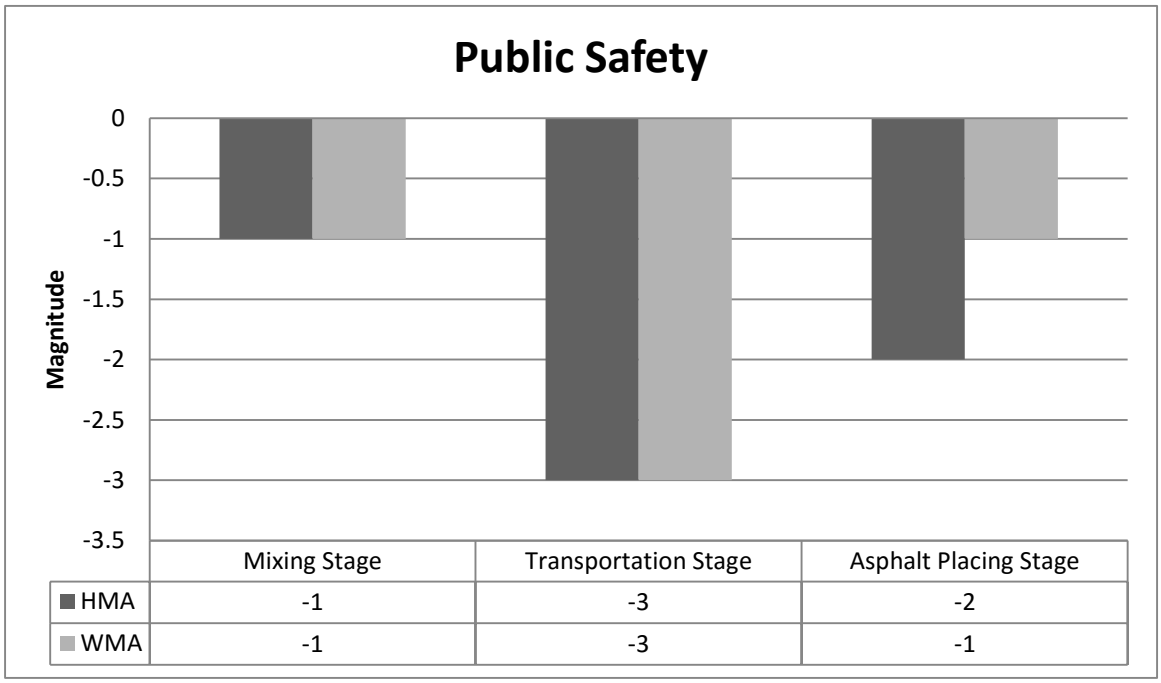
Figure(6.8) Magnitudes of the workers safety when using both methods.



Figure(6.9) Magnitudes of the workers' health when using both methods.

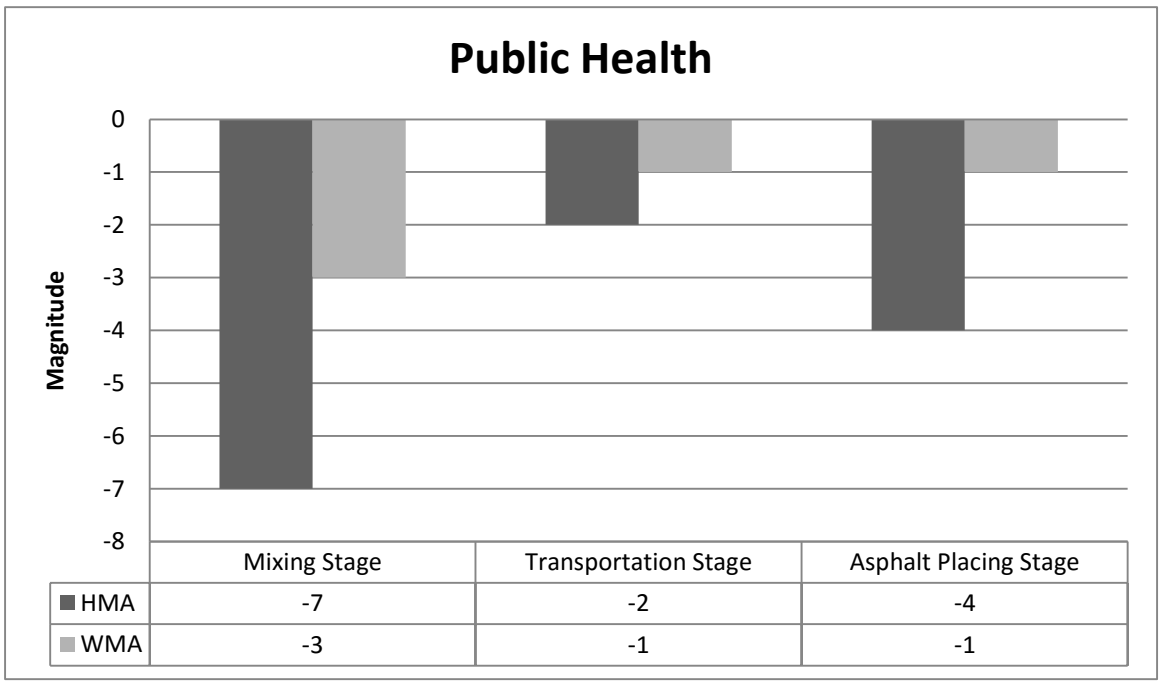


Figure(6.10) Magnitudes of the workers support when using both methods.



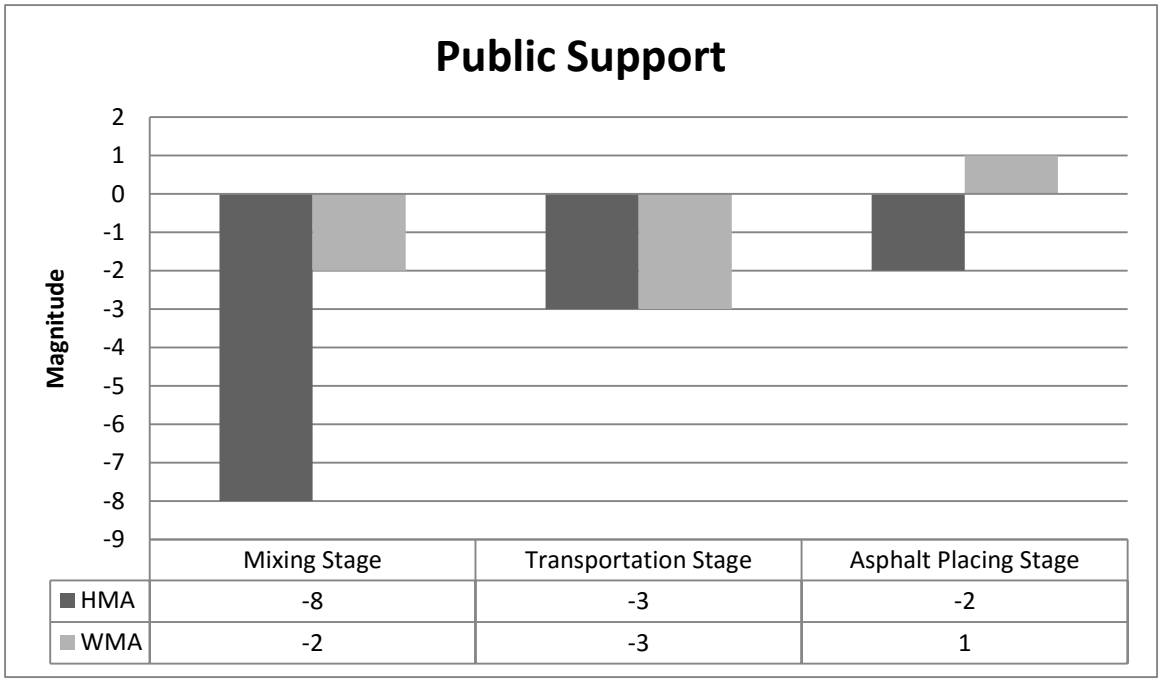
	Mixing Stage	Transportation Stage	Asphalt Placing Stage
HMA	-1	-3	-2
WMA	-1	-3	-1

Figure(6.11) Magnitudes of the public safety impact when using both methods.

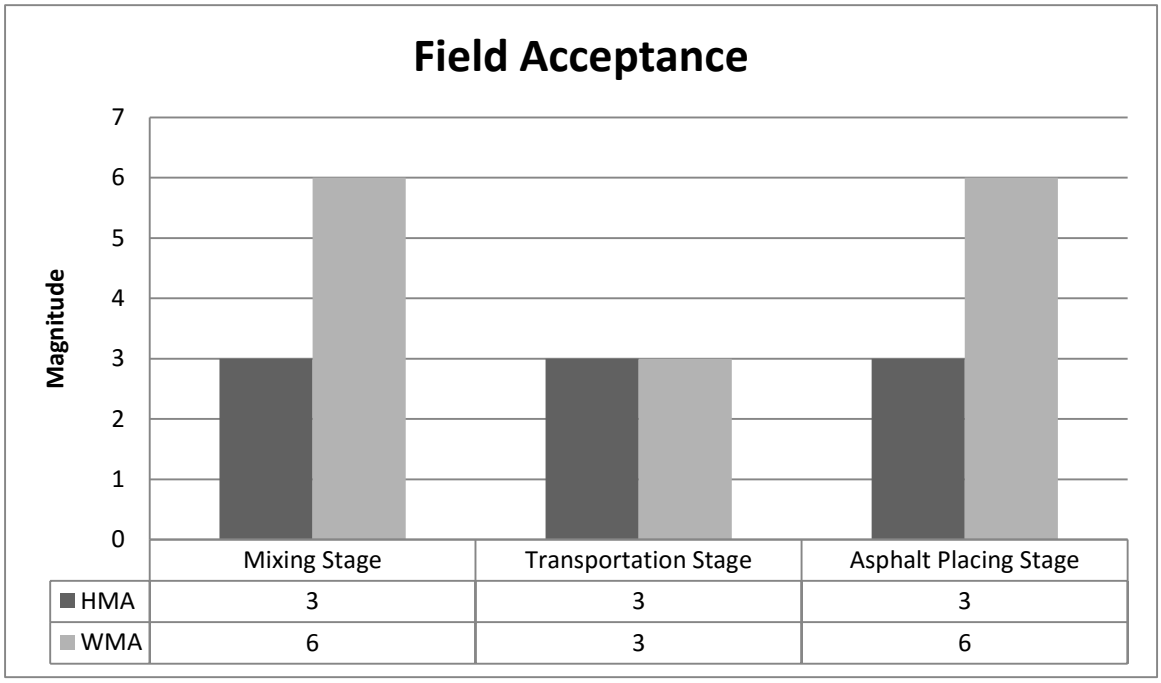


	Mixing Stage	Transportation Stage	Asphalt Placing Stage
HMA	-7	-2	-4
WMA	-3	-1	-1

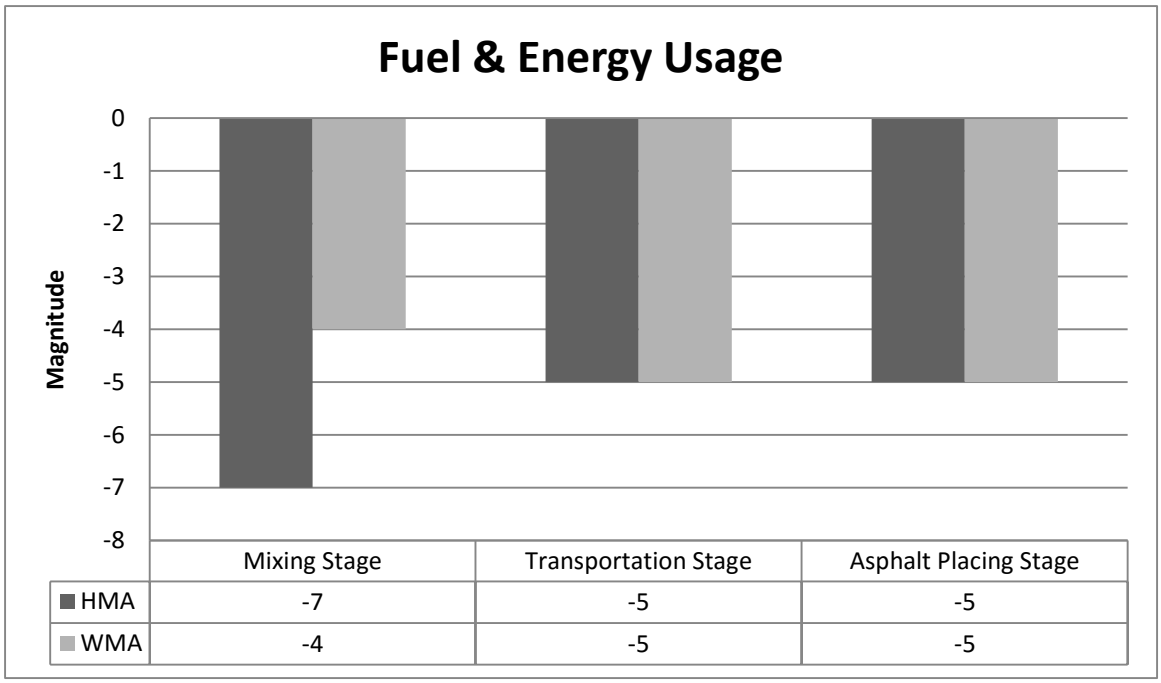
Figure(6.12) Magnitudes of the public health when using both methods.



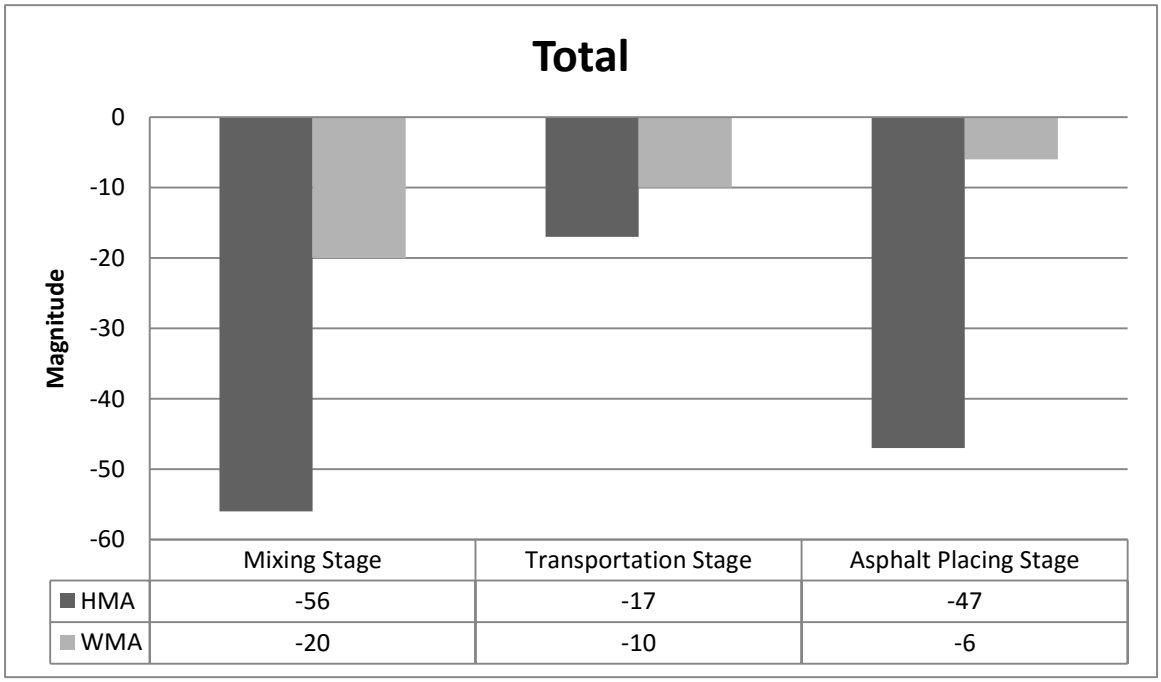
Figure(6.13) Magnitudes of the public support when using both methods.



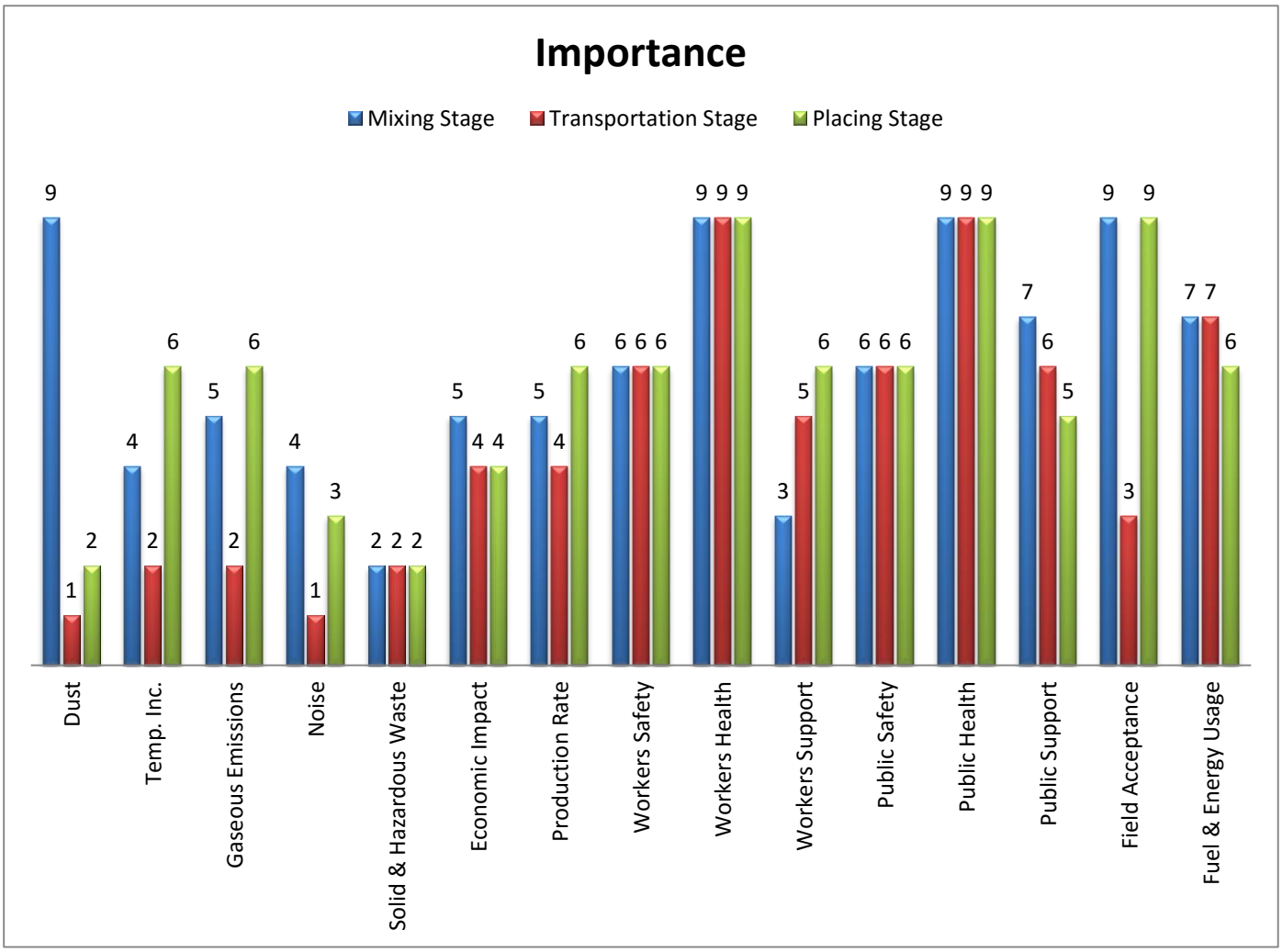
Figure(6.14) Magnitudes of the field acceptance when using both methods.



Figure(6.15) Magnitudes of the fuel and energy usage when using both methods.



Figure(6.16) Total Magnitudes when using both methods.



Figure(6.17) Importance of each environmental impact for each paving stage

CHAPTER (7)

CONCLUSIONS & RECOMMENDATIONS

7.1 Conclusions

1. According to the literature review HMA has a great impact on the environment as its emissions include harmful gases such as carbon monoxide, carbon dioxide, nitrous oxides, sulphur dioxide and others which have several effects locally (Workers' health, public health… Etc.) , and also globally (Greenhouse gases, Global warming… Etc.).
2. Guidelines for environmental impact assessment for road construction in Egypt were established in the thesis, it is clear that according to the Egyptian law asphalt plant projects are considered *Grey List Projects which may result in significant environmental impact* and other road construction projects including runways, helicopter landing areas, large transportation systems, and even internal highways in cities are considered *Black List Projects which require complete EIA due to their potential impacts*.
3. The primary advantages of warm mix asphalt are; reduced energy consumption, reduced emissions and reduced viscosity at working temperatures. The emissions reduction is an important advantage but how beneficial it really is in practice for asphalt producers and buyers is entirely dependent on environmental awareness and regulations in each country.
4. It was concluded from the survey conducted among 52 professionals from various sectors of the paving industry that the asphalt mixing stage is considered of worst environmental impact as it scored 140 points on a scale of 156 points while the placing stage came second scoring 111 points and the transportation stage last scoring 80 points.
5. The matrix analysis concluded that the WMA technique is beneficial on different stages of asphalt road construction. The improvement scored for each stage was 64% for mixing stage, 41% for transportation stage and 87% for placing stage.

6. According to the cost analysis WMA will not include a great increase in the mix cost (from 1 to 8 percent increase).
7. The conclusion drawn from the information about warm mix asphalt's advantages and disadvantages, general information about Egypt and the results from the field research, the survey and the analysis, is that warm mix asphalt is a viable option for the paving industry in Egypt.

7.2 Recommendations

The proposed recommendations for future research work can be summarized as follows:

1. Laboratory and field studies should be conducted to evaluate different warm mix asphalt technologies, properties of mix materials and properties of additives used should be studied accurately to conclude which technology is the most suitable from the material properties point of view.
2. A study of health and safety during road construction in Egypt should be conducted as it is clear that health and safety of road construction workers in Egypt is not considered as important as it should be.
3. Risk analysis regarding the change of the method of road construction should be studied to give exact information which will encourage contractors to use alternatives to the hot mix asphalt method.