ANALYSIS OF HUMAN FACTORS AND PROCEDURAL FAILURES IN LANDSCAPING AND HORTICULTURAL SERVICES USING HAZOP

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İPEK SARIÖZ AĞCA

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submitted by **İPEK SARIÖZ AĞCA** in partial fulfillment of the requirements for the degree of **Master of Science in Occupational Health and Safety Department, Middle East Technical University** by,

Prof. Dr. Halil Kalıpçılar
Dean, Graduate School of **Natural and Applied Sciences** _____

Prof. Dr. Mahmut Parlaktuna
Head of Department, **Petroleum and Natural Gas Eng.** _____

Prof. Dr. Mahmut Parlaktuna
Supervisor, **Petroleum and Natural Gas Eng., METU** _____

Examining Committee Members:

Prof. Dr. Nuray Demirel
Mining Eng., METU _____

Prof. Dr. Mahmut Parlaktuna
Petroleum and Natural Gas Eng., METU _____

Prof. Dr. Emine Bayraktar
Chemical Eng., Ankara University _____

Date: 04.09.2019

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Surname: İpek Sarıöz Ağca

Signature:

ABSTRACT

ANALYSIS OF HUMAN FACTORS AND PROCEDURAL FAILURES IN LANDSCAPING AND HORTICULTURAL SERVICES USING HAZOP

Sarıöz Ağca, İpek
Master of Science, Occupational Health and Safety
Supervisor: Prof. Dr. Mahmut Parlaktuna

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There are many activities carried out in parks, gardens, and other green fields of municipalities. Since these green fields are public areas, both employees and passers-by are confronting with hazards and risks of the performed activities. Therefore, it becomes even more important to determine the risks that may arise and take precautions. Landscaping and horticultural services include mostly human-driven activities than automated ones. The main objective of this study is to analyze human factors and procedural failures in landscaping and horticultural services by using Hazard and Operability (HAZOP) methodology. In this scope, landscaping and horticultural activities of a metropolitan municipality were examined in four main topics as; green field services, cleaning services, construction and maintenance services, and auxiliary works. Firstly, guide words were determined and then deviations were detected by using the guide words for each activity. Possible causes and consequences of the deviations, existing barriers, and proposed improvements were determined. Findings showed that unsafe behaviors of employees, noncompliance of workplace regulations and unawareness of chemical, electrical, and biological hazards cause the maximum number of failures among other factors. This study could be used by any landscaping and horticultural service provider for

analyzing human and procedure-related failures in landscaping and horticultural services.

Keywords: Human HAZOP, Procedure HAZOP, Occupational health and safety (OHS), Landscaping and horticultural services, Risk assessment

ÖZ

PARK VE BAHÇE İŞLERİNDE İNSAN FAKTÖRLERİ VE PROSEDÜREL HATALARIN HAZOP TEKNİĞİ İLE ANALİZİ

Sarıöz Ağca, İpek
Yüksek Lisans, İş Sağlığı ve Güvenliği
Tez Danışmanı: Prof. Dr. Mahmut Parlaktuna

Eylül 2019, 112 sayfa

Belediyelerin park, bahçe ve diğer yeşil alanlarında birçok aktivite yürütülmektedir. Bu yeşil alanların kamuya açık alanlar olması, yürütülen faaliyetlerdeki tehlike ve risklerle hem çalışanların hem de bu alanlardan geçen kişilerin karşı karşıya kalmasına sebep olmaktadır. Dolayısıyla ortaya çıkabilecek riskleri belirlemek ve önlem almak daha da önemli hale gelmektedir. Park ve bahçe hizmetleri, otomatik sistemler yerine daha çok insan kaynaklı aktiviteler içermektedir. Bu çalışmanın temel amacı, park ve bahçe işlerinde insan faktörleri ve prosedürel hataların Tehlike ve İşletilebilirlik (HAZOP) metodolojisi kullanılarak analiz edilmesidir. Bu kapsamda bir büyükşehir belediyesinin park ve bahçe faaliyetleri; yeşil alan hizmetleri, temizlik hizmetleri, inşaat ve bakım hizmetleri ile yardımcı unsurlar olmak üzere dört ana başlıkta incelenmiştir. Öncelikle, rehber kelimeler belirlenmiş ve daha sonra her faaliyet için rehber kelimeler kullanılarak sapmalar tespit edilmiştir. Sapmaların olası nedenleri ve sonuçları, mevcut önlemler ve önerilen iyileştirmeler belirtilmiştir. Bulgular, çalışanların güvensiz davranışlarının, iş yeri kurallarına uymamanın ve kimyasal, elektriksel ve biyolojik tehlikelerin farkında olmamanın diğer faktörlere göre daha fazla hataya neden olduğunu göstermiştir. Bu çalışma, park ve bahçe hizmetlerinde

insan ve prosedürle ilgili hataları analiz etmek için herhangi bir park ve bahçe hizmeti sağlayıcısı tarafından kullanılabilir.

Anahtar Kelimeler: İnsan HAZOP, Prosedür HAZOP, İş sağlığı ve güvenliği (İSG), Park ve bahçe hizmetleri, Risk değerlendirmesi

To my dearest husband and beloved parents...

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LIST OF ABBREVIATIONS

ABBREVIATIONS

BLS	Bureau of Labor Statistics (United States)
ETA	Event Tree Analysis
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FMEA	Failure Mode and Effect Analysis
FMECA	Failure Mode, Effects and Criticality Analysis
FTA	Fault Tree Analysis
HAZOP	Hazard and Operability
HRA	Human Reliability Analysis
ICI	Imperial Chemical Industries
ILO	International Labor Organization
ISIC	International Standard Industrial Classification of All Economic Activities
NACE	Statistical classification of economic activities in the European Community (French: Nomenclature statistique des activités économiques dans la Communauté européenne)
OHS	Occupational Health and Safety
P&ID	Process piping and Instrumentation Diagrams
PFD	Process Flow Diagram
PHA	Preliminary Hazard Analysis
PPE	Personal Protective Equipment
PRA	Probabilistic Risk Assessment
SDS	Safety Data Sheet
UN	United Nations
UNESCO	United Nations Educational, Scientific, and Cultural Organization

UNIDO	United Nations Industrial Development Organization
US	United States

CHAPTER 1

INTRODUCTION

1.1. Background

In Turkey, according to Occupational Health and Safety Law No. 6331, hazard class refers to the hazard group determined for a workplace by taking into consideration the nature of the work carried out, the materials used or produced at each stage of the work, the equipment, method and types of production and other points regarding working conditions, and environment in terms of occupational health and safety (OHS). While determining the hazard class of a workplace, the main activities performed are taken into consideration [1].

According to the "Communiqué on Occupational Health and Safety Hazard Classes", there are three hazard classes as low hazardous, hazardous, and highly hazardous. Landscaping and horticultural works of municipalities are under the code 81.30 (landscaping and maintenance activities) and indicated as low hazardous. Whereas, hard coal mining under the code 05.10 and metal mining under the code 07 are indicated as highly hazardous. In addition, manufacturing of chemicals and chemical products under the code 20 includes activities indicated as hazardous and highly hazardous [2].

Although landscaping and horticultural activities are indicated as low hazardous, according to Republic of Turkey Social Security Institution statistics, 1,271 accidents were happened in 2017, whereas this number was 3,410 for hard coal mining, 1,622 for metal mining, and 2,877 for manufacturing of chemicals and chemical products (Figure 1.1) [3].

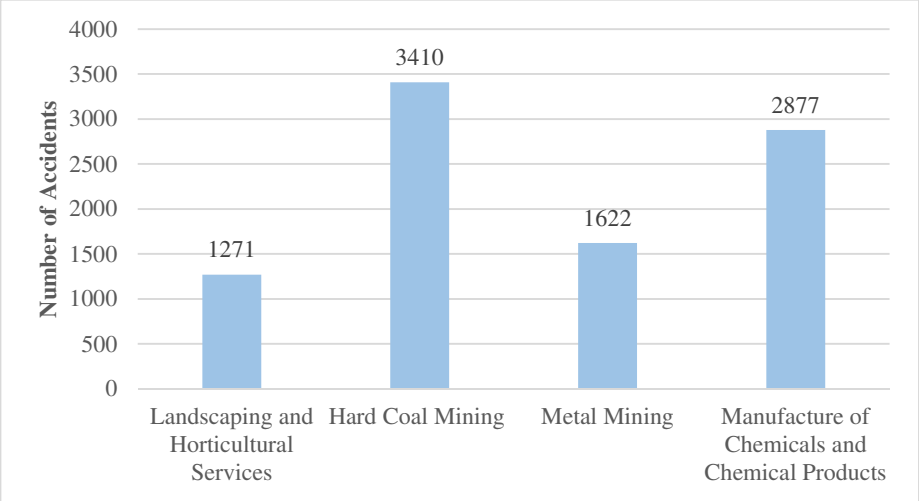

Figure 1.1. Number of Accidents in Landscaping and Horticultural Services, Hard Coal Mining, Metal Mining and Manufacture of Chemicals and Chemical Products in Turkey in 2017 [3]

In addition, number of fatal occupational accidents in landscaping and horticultural services in 2017 was 11, while this number was 20 for hard coal mining, 16 for metal mining, and 10 for manufacturing of chemicals and chemical products (Figure 1.2) [3].

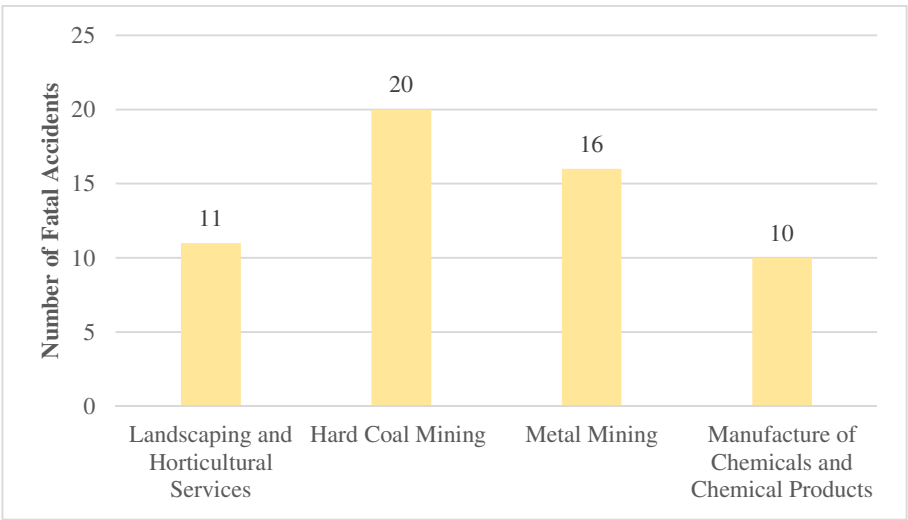

Figure 1.2. Number of Fatal Accidents in Landscaping and Horticultural Services, Hard Coal Mining, Metal Mining and Manufacture of Chemicals and Chemical Products in Turkey in 2017 [3]

1.2. Statement of the Problem

There are many activities carried out in parks, gardens, and other green fields of municipalities. Since these green fields are public areas, both employees and passers-by are confronting with the hazards and risks of the performed activities. Therefore, it becomes even more important to determine the risks that may arise and take precautions.

Lawn mowing, turf laying, flower planting, shrub pruning, pest and disease treatment, cleaning of decorative ponds, hardscape construction, and maintenance of lighting elements are some of the activities performed in landscaping and horticultural services. Slips, trips and falls, injuries, musculoskeletal disorders, skin, eye, and respiratory system irritations, poisoning, dehydration, and heat and cold stress are some of the hazards and risks that may be encountered in these activities.

OHS Law No. 6331 states that risk assessments shall be conducted in terms of OHS to all works, workplaces, and the employers and employees of these workplaces. In addition, necessary precautions shall be taken as a result of these risk assessments [1].

For the risk assessment applications in landscaping and horticultural services, risk matrices and Fine-Kinney methods are generally used in Turkey. In these methods, evaluations and risk scoring are subjected to the practitioner and because of the final risk score, some important risks may be missed.

1.3. Objectives and Scope of the Study

The main objective of this study is to analyze human factors and procedural failures in landscaping and horticultural services by using Hazard and Operability (HAZOP) methodology.

The scope of this study includes examination of landscaping and horticultural activities of a metropolitan municipality. Nineteen activities were evaluated in four main topics as; green field services, cleaning services, construction and maintenance services, and auxiliary works.

1.4. Research Methodology

Landscaping and horticultural services include mostly human-driven activities than automated ones. Therefore, HAZOP method was implemented to see the procedure and human related hazards and risks in landscaping and horticultural services. Firstly, for collecting data, field visits were done. After the field visits and examination of the activities, guide words were determined. Deviations were detected by using the appropriate guide words for each activity. Then, examinations including possible causes and consequences of the deviations, existing barriers, and proposed improvements were recorded in the HAZOP worksheets.

1.5. Expected Contributions of the Thesis

This study recommends a qualitative risk analysis of landscaping and horticultural activities by using HAZOP technique. The primary contribution of the study is that it is the first application of HAZOP technique to landscaping and horticultural activities. On the other hand, the current literature lacks information on analyzing human and procedure related failures in landscaping and horticultural activities by using HAZOP method. This study represents a first example in the country.

In addition, the current risk assessment methods used in this sector are based on probability and severity values. The values are arbitrary and final risk rankings may vary depending on the practitioner. This study presents a new approach to the risk analysis implementations in the sector and could be used by any landscaping and horticultural service provider.

1.6. Overview of the Thesis

This thesis consists of six chapters. Following the Introduction chapter, a comprehensive literature survey is presented in Chapter 2. Firstly; statistical, industrial, and hazard classification of landscaping and horticultural services and the activities carried out in the sector, and possible hazards and risks are given in the literature survey. Then, occupational accident statistics of landscaping and

horticultural activities are described. Finally, a brief information on risk assessment and detailed information on HAZOP technique are given.

The third chapter represents information on the study area and the implemented method. In Chapter 4, landscaping and horticultural services are examined in four main topics as; green field services, cleaning services, construction and maintenance services, and auxiliary works. Then, HAZOP technique is implemented to those activities by focusing humans and procedures. Chapter 5 presents main conclusions of the study and finally in Chapter 6, recommendations for future studies are given.

CHAPTER 2

LITERATURE SURVEY

2.1. Landscaping and Horticultural Services in Statistical, Industrial, and Hazard Classifications

The International Standard Industrial Classification of All Economic Activities (ISIC) is used to compare statistical data at the global level. Some countries have used ISIC as their national activity classification or utilized it as a basis for developing their national industrial classification since 1948 when the original version of ISIC was adopted. To analyze statistical data, a number of international bodies such as, the United Nations (UN), the International Labor Organization (ILO), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the United Nations Industrial Development Organization (UNIDO) use ISIC [4].

The European Union (EU) uses NACE which is the abbreviation of Statistical classification of economic activities in the European Community (French: ***N****omenclature statistique des* ***a****ctivités économiques dans la* ***C****ommunauté* ***e****uropéenne*) since 1970. NACE is derived from ISIC and the usage of NACE is mandatory within the European Statistical System. In order to make sure international comparability, the definitions and guidelines formed for the usage of NACE within EU are matching with those published for ISIC.

Under section N (Administrative and Support Service Activities), division 81 (Services to buildings and landscape activities), group 81.3 (Landscape service activities), Landscape service activities are classified as 81.30 and this class includes [5]:

- Planting, care, and maintenance of parks and gardens for private and public housing, public and semi-public buildings like schools and hospitals, municipal grounds, highway greenery, and industrial and commercial buildings,
- Greenery for buildings like roof and indoor gardens, sports grounds, play grounds, lawns for sunbathing and other recreational parks and stationary and flowing water like swimming pools, watercourses and ponds,
- Plants which are used for protection against noise, wind, erosion, visibility, and dazzling.

In Turkey, according to OHS Law No. 6331, hazard class refers to the hazard group determined for a workplace by taking into consideration the nature of the work carried out, the materials used or produced at each stage of the work, the equipment, method and types of production, and other points regarding working conditions and environment in terms of OHS. While determining the hazard class of a workplace, the main activities performed are taken into consideration [1].

According to the "Communiqué on Occupational Health and Safety Hazard Classes", in case of a doubt in determination of the main work, the purpose of establishment of the workplace shall be considered. If more than one activity fitting to main job description is carried out in the workplace, the activity with high hazard class is taken as basis. There are three hazard classes as low hazardous, hazardous, and highly hazardous. Landscaping and horticultural works of municipalities are under the code 81.30 (landscaping and maintenance activities) and indicated as low hazardous.

81.30 is the landscaping and maintenance activities and includes [2]:

- 81.30.01: Sewing and care of protective plants against noise, wind, erosion, reflection,
- 81.30.05: Planting and maintenance of green areas for sport fields (such as football grounds, golf courses), playgrounds, lawns for sun bath and other amusement parks,

- 81.30.90: Landscaping and maintenance of other landscaping projects (planting, maintenance and repair of parks, gardens, and green areas).

2.2. Activities, Hazards, and Risks in Landscaping and Horticultural Services

Noise, construction, machinery, lifting, chemicals, and weather related hazards are only a few of the hazards that workers of landscaping and horticultural services are confronted.

The main activities, hazards, and risks that may be faced in landscaping and horticultural services are given in the following sections.

2.2.1. Soil Preparation and Grading Services

Soil preparation treats existing soil to the quality required for planting and landscaping by loosening the soil and mixing soil improvers such as surface soil, humus, and fertilizer. During grading, the floor is moved to desired heights and contours by moving the soil.

The main hazards and risks that may be encountered in these works are as follows [6]:

- Accidents while using equipment and machines
- Slips, trips, and falls because of rough terrain
- Vehicle accidents – trucking
- Cuts and amputations
- Hearing loss
- Traffic accidents

2.2.2. Hardscape Construction Services

Hardscape construction services include construction of retaining walls, hard flooring, pedestrian paths, water elements, wood structures, and ensuring that workers are safely transported to and from the working area.

The main hazards and risks that may be encountered in these works are as follows [6]:

- Cuts and amputations
- Hearing loss
- Injuries caused by lifting
- Slips, trips, and falls
- Crash injuries
- Pits and cavities at the excavation sites
- Vehicle/traffic accidents

2.2.3. Planting Services

Planting activities include planting trees, hedges, and lawns, tree staking, picking, and ensuring that workers are safely transported to and from the workplace, and housekeeping of the working area [6].

Staking is to provide support in order to protect the newly planted trees from the shaking of the wind and root movements by connecting the trees to the penetrated stakes around the newly planted trees [7].

The main hazards and risks that may be encountered in these works are as follows [6]:

- Injuries caused by lifting
- Heat stress
- Cuts and hand injuries
- Slip, trip, and falls
- Vehicle/traffic accidents

2.2.4. Lawn and Landscape Maintenance Services

These services include activities like lawn mowing, pruning, fertilizing, general cleaning, and ensuring that workers are safely transported to and from the workplace.

The main hazards and risks that may be encountered in these works are as follows [6]:

- Cuts, amputations, and hand and eye injuries
- Exposure to chemicals

- Hearing loss
- Ergonomic risks
- Vehicle/traffic accidents

2.2.5. Tree Care Services

These services include activities like tree pruning, dismantling, tree health services, supporting, tree transplantation, grafting, fertilizing, lightning protection, and ensuring that workers are safely transported to and from the workplace.

Many hazards that will be confronted in tree care services are potentially fatal and main hazards and risks that may be encountered in these works are as follows [6]:

- Crash injuries
- Cuts and amputations
- Eye injuries
- Hearing loss
- Electric shock
- Slips, trips, and falls
- Vehicle/traffic accidents

2.2.6. Working in Confined Spaces

Many workplaces contain space that can be considered as closed space. Although these spaces are not designed for people, they have enough space to allow employees to go in and do certain tasks [8].

Confined spaces containing hazardous substances or hazardous conditions (insufficient oxygen levels, ventilation and etc.) that may cause injury or death, require safe working measures [9].

Open air areas such as deep pits and cavities, wells, sewage plants, storage tanks, tankers are some examples of confined spaces [10].

In confined spaces, there are several hazards such as; poor air quality, chemical exposures, fire, electric shock, extreme temperatures, noise, biological hazards. Conditions, such as the fact that it is more difficult for the employee to escape and more difficult to rescue the victim, very quickly change of conditions and insufficient natural ventilation for the quality of breathable air make working in confined spaces more dangerous than working in other areas [11].

When the oxygen level is 20.8 ± 0.2%, entry to the confined space is safe but when this level drops to 19.5%, an oxygen deficient environment is formed [12].

Work permit for confined spaces indicates that the necessary precautions were taken and controls were done to ensure a safe working environment in a confined space before employees are allowed to enter [9].

2.2.7. Thermal Stress

Working in hot environment can cause stress to the body's cooling system. Heat can cause heat-related illnesses, disabilities or even death if combined with stresses such as heavy physical work and dehydration. The body continuously generates heat and gives it to the environment. The harder the work is done; the more heat the body needs to lose. People over the age of forty need to be more careful in hot weather because their ability to lose heat with sweating decreases with age. Heat stress can also affect young and healthy people. In order for the body temperature to remain at normal level, the amount of water taken should be equal to the amount of water that the body sweats. Unfortunately, sweat does not readily evaporate in damp and still weather.

There are three basic conditions that can occur as a result of the body overheating:

- Heat cramping
- Heat exhaustion
- Heat stroke

Heat cramping occurs when the body loses water as a result of excessive sweating and the lost water cannot be removed by only drinking water. During working or later at home, painful cramps can occur in the arms, legs or stomach.

Heat exhaustion is caused by disruption of the body's cooling system as a result of insufficient water and salt intake. Excessive sweating, moist skin, and body temperature above 38°C are some of the symptoms. The person suffering from heat exhaustion may get tired, seems unhappy and unwell, may be very thirsty and breathe fast. Heat exhaustion can lead to fatal heat stroke.

Heat stroke can kill a person very quickly. Sweating stops as the body uses all its water and salt, and body temperature may increase rapidly. Body temperature above 41°C, fatigue, hot, dry and red skin, headache, and dizziness are some of the symptoms of heat stroke [13].

On the other hand, any employee may be at risk of cold stress while working in a cold environment like working outdoors in cold weather for long periods. Extreme cold and its effects are changing across different regions of the country.

In a cold environment, to maintain its temperature, body is forced to work harder. Heat can leave the body more quickly, when temperature drops below normal level and speed of the wind increases.

Cold stress arises from decreasing of skin temperature and consequently internal body temperature. As a result, serious health problems, tissue damage, and possibly death may occur. Body uses most of its energy to keep its internal temperature warm in a cold environment. In the course of time, blood flow is shifted from extremities and outer skin to the core of the body. This causes rapid cooling of the skin and extremities, and risk of frostbite and hypothermia increases. If this case is combined with wet environment exposure, trench foot may also occur.

There are three common cold caused cases:

- Hypothermia

- Frostbite
- Trench foot

Hypothermia occurs when body loses heat faster than it can generate and body temperature drops less than 35°C. It may happen at very cold temperatures; however, it may also happen even at cool temperatures (above 4°C), if body is exposed to rain or sweat. Shivering, loss of coordination, confusion, and disorientation are the early symptoms of hypothermia. These symptoms will get worse and shivering may stop, if the body temperature continues to fall. Blue skin, slowed breathing and pulse, and loss of consciousness are the moderate to severe symptoms and can cause death of a person.

Frostbite is an injury as a result of freezing of the skin and underlying tissues. Fingers, toes, nose, ears, cheeks, and chin are the most often affected areas with a loss of feeling and color. As the temperature gets colder, frostbite will occur more quickly and in severe cases, amputation may be required.

Trench foot is caused by exposure to cold and wet conditions for long time, and may occur even at 15.5°C, if the feet are continuously wet. Since wet feet lose heat 25 times faster than dry ones, body shuts down circulation of blood in the feet to prevent heat loss and injury occurs [14], [15].

2.3. Occupational Health and Safety Practices in Landscaping and Horticultural Activities in the World

In the United States (US), especially in peak season, the number of people working in landscaping and horticultural works is twice as high or more. This increase can jeopardize safety and raise the potential of the occurrence of an accident. Most of the accidents happened in horticultural works are caused by slips, trips, and falls, fires, inappropriate machine or equipment guards, chemical and electrical hazards. Most workplaces do not conduct regular safety audits of their activities in this sector. This may have several reasons, but most common stated reason is that the owner or manager of the workplace is “too busy” [16].

The works that are done in the scope of landscaping and horticultural works in Australia are similar to ones in Turkey. Some of them are as follows [17]:

- Tree pruning, planting, and removal
- Erosion and sediment control
- Mowing
- Landscape lighting
- Pest and disease management
- Plantings and turf renovation
- General landscape maintenance

There are several ways to treat plants for pests and diseases. Pesticide sprays and soil treatments are the conventional ways used for years. Due to the potential exposure to hazardous chemicals, pest and disease control of the trees on the street can be difficult. Therefore, in order to treat tree pests and diseases, a non-toxic and eco-friendly application like tree injection is used. Tree injection is an effective, environmentally friendly and very fast responding disease reduction method. Spraying of chemicals causes chemicals to penetrate into the soil continuously, whereas smaller volume of chemicals is used for tree injection and application is easier. As shown in Figure 2.1, applications are done directly to the tree. Thus, chemical exposure of people and environment is minimized, and achievement of the targeted effect is guaranteed every time [18].

The purpose of tree services is to maximize the life of open-air areas by selection, planting, and scheduled maintenance of trees. In Australia, a management system is used for tree supervision. First of all, tree experts make field visits and collect information about trees, and then store this information in a central database. This database is used to identify the tree's requirement of maintenance and the urgency of the work to be done [19].

Figure 2.1. Tree Injection [20]

Besides these, there are certificate and diploma courses for the ones who want to build a career in landscaping, horticulture, and parks and gardens sectors.

Some of them are [21]–[24] :

- Certificate II in Parks and Gardens
- Certificate II in Landscaping
- Certificate III in Landscape Construction
- Certificate III in Parks and Gardens
- Certificate IV in Parks and Gardens
- Certificate IV in Horticulture
- Diploma of Parks and Gardens Management
- Advanced Diploma of Horticulture

With Certificate II in Parks and Gardens, one can be qualified as gardener/parks and gardens worker and can participate in work health and safety processes, apply chemicals under supervision, apply a range of treatments to trees, operate basic machinery and equipment.

With Certificate III in Parks and Gardens, one can be qualified as parks and gardens tradesperson. Workplace monitoring, ornamental plant and lawn cultivation, irrigation and drainage installation, machine maintenance, and plant pest and disease controls are the primary qualifications of parks and gardens tradesperson.

With Certificate IV in Parks and Gardens, one can be qualified as parks and gardens supervisor and can cost a project, supervise the workers, maintain occupational health and safety processes.

2.4. Occupational Accident Statistics of Landscaping and Horticultural Activities in the World

In 2016, 11 workers were fatally injured in landscaping services in California, while this number was nearly tripled in 2017 with 32 workers [25].

Landscape and horticultural services are taking place in the scope of cleaning and landscape maintenance activities in Singapore. In Workplace Safety and Health Report which was published by the Ministry of Manpower, it is stated that 2 fatal injuries happened in 2017 while this number was 1 in 2018 and caused by slips, trips, and falls. There were also 131 and 210 minor injuries reported in this sector in 2017 and 2018, respectively. Slips, trips, and falls, struck by moving objects, and cuts by objects were the top three accident types of minor injuries in 2018 [26].

According to the United States Department of Labor, Bureau of Labor Statistics (BLS), 53 fatal injuries happened to first-line supervisors of landscaping, lawn service, and grounds keeping employees in 2017. In addition to this, transportation incidents were the leading event with the number 42 of 109 fatal injuries happened to landscaping and grounds keeping workers [27].

In the same year, there were totally 11,250 cases involving days away from work because of nonfatal occupational injuries and illnesses in landscaping services industry. Sprains, strains, and tears were the uppermost reason with 2,660 cases and cuts, lacerations, and punctures were the following reason with 2,470 cases [28].

According to Republic of Turkey Social Security Institution statistics, in landscaping and horticultural services 1,271 occupational accidents happened in 2017 whereas this number was 966 in 2016, 779 in 2015 and 586 in 2014 (Figure 2.2) [3].

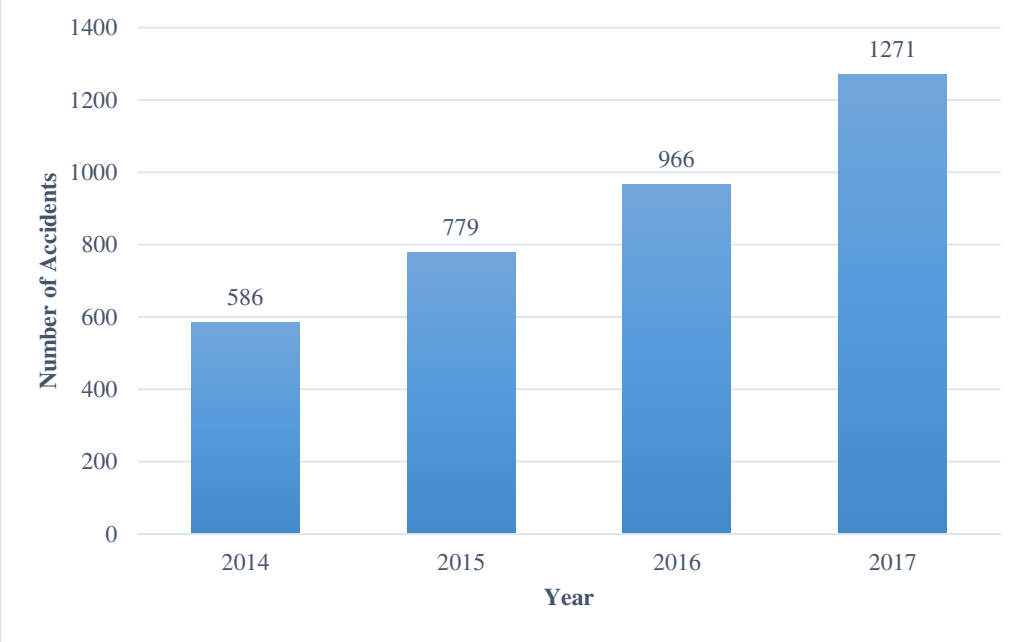

Figure 2.2. Number of Occupational Accidents in Landscaping and Horticultural Services in Turkey between Years 2014 and 2017 [3]

In 2017, 594 of 1,271 occupational accidents happened with no days away from work while 30 of them happened with one day away from work, 61 of them happened with two days away from work, 80 of them happened with three days away from work, 20 of them happened with four days away from work, and 486 of them happened with five and more days away from work (Figure 2.3). Data for the years 2014, 2015, and 2016 can be seen from Figure 2.3 [3].

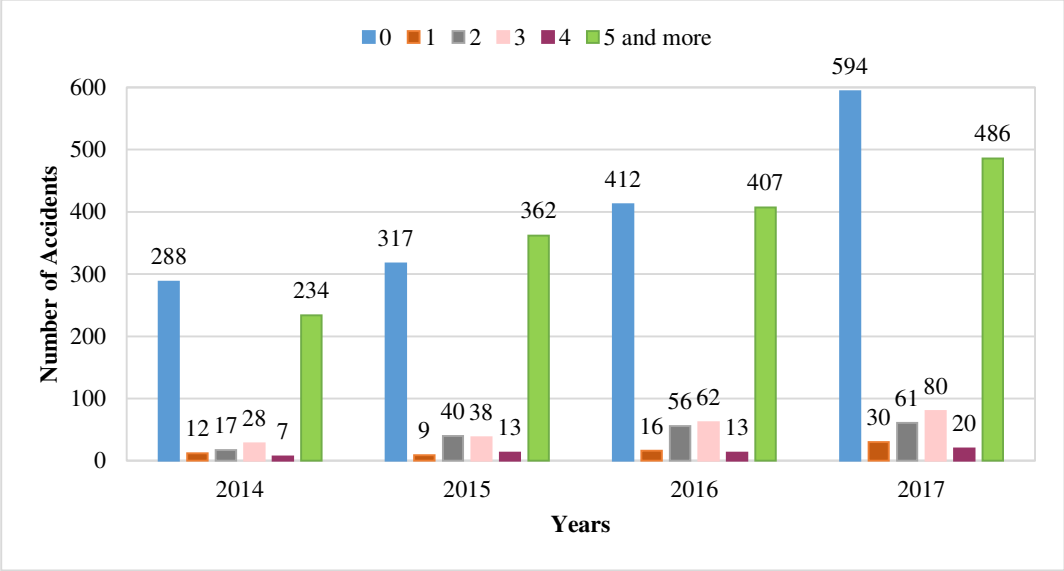

Figure 2.3. Number of Occupational Accidents by Incapacity Days in Landscaping and Horticultural Services in Turkey between Years 2014 and 2017 [3]

Apart from that, number of fatal occupational accidents in 2017 was 11. This number was 14 for 2016, 12 for 2015, and 4 for 2014 (Figure 2.4) [3].

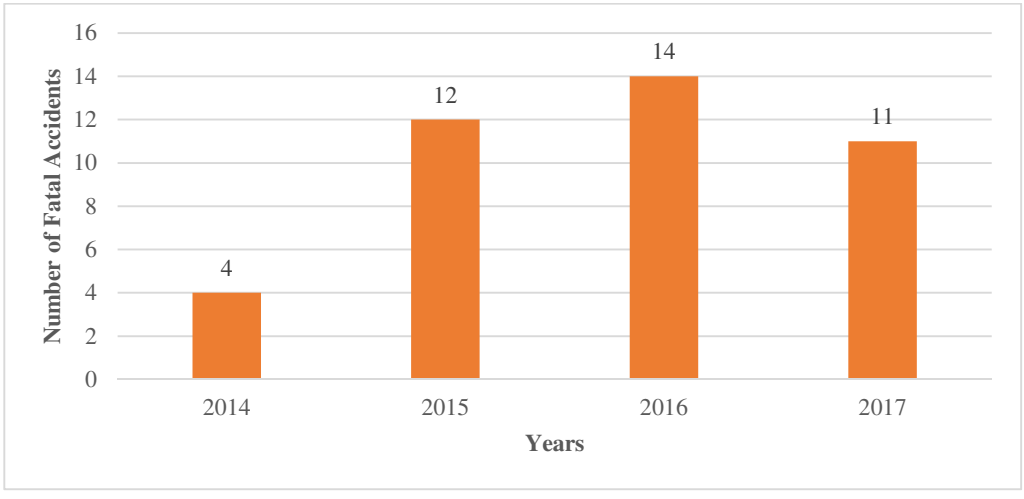

Figure 2.4. Number of Fatal Occupational Accidents in Landscaping and Horticultural Services in Turkey between Years 2014 and 2017 [3]

2.5. Risk Assessment

Risk assessment is the process of carrying out risk analysis and risk evaluation together. Risk analysis covers identifying hazards and hazardous events, determining consequences, and establishing risks. Risk evaluation includes evaluation of risks, proposing measures for reducing risks, and assessing alternative risk reducing measures [29].

Risk assessments can be performed with either qualitative or quantitative methods. In qualitative risk assessment methods, probabilities and consequences are determined purely qualitatively and in quantitative risk assessment methods, numerical estimates are done for probabilities, consequences, and sometimes together with related uncertainties [29].

Some of the risk assessment methods are as follows [30], [31]:

- Preliminary Hazard Analysis (PHA)
- What-if
- Hazard and Operability (HAZOP)
- Failure Mode and Effect Analysis (FMEA)
- Failure Mode, Effects, and Criticality Analysis (FMECA)
- Fault Tree Analysis (FTA)
- Event Tree Analysis (ETA)
- Human Reliability Analysis (HRA)
- Probabilistic Risk Assessment (PRA)

2.6. Hazard and Operability Analysis (HAZOP)

HAZOP is a systematic analysis of a process or procedure in order to define and assess problems that may cause risks to staff or equipment or efficient operation and is a qualitative method based upon guide words [32]. The concept of HAZOP was built up in the early 1970s at the Imperial Chemical Industries (ICI) based in United Kingdom. In the following years, improvements have been made in HAZOP

procedure; however, it fundamentally stayed almost identical in form and context in the original ICI system [33].

Examples of basic guide words are given in *Table 2.1* [29], [34].

Table 2.1. *Basic Guide Words, Meanings and Examples*

Guide words	**Meaning**	**Example**
No or none	No part of the design is achieved	No flow No data or control signal passed
More	Quantitative increase	Higher temperature
Less	Quantitative decrease	Lower pressure than normal
As well as	Design purpose is achieved, however something else is present	Impurities present Other valves closed at the same time
Part of	Only some of the design purpose is achieved	Only part of an intended fluid transfer takes place
Reverse	Logical opposite of the design intent	Reverse chemical reactions Back flow when the system shuts down
Other than	Another result is achieved instead of the purpose	Transfer of wrong material Liquid in gas piping
Early	Earlier occurrence relative to clock time	The signals arrive too early
Late	Later occurrence relative to clock time	Late cooling or filtration
Before	Occurrence before expected relating to the sequence of order	Too early mixing or heating
After	Occurrence after expected relating to the sequence of order	Too late mixing or heating

Additional guide words can be used, if only they are identified before the study starts [29], [34].

Process piping and instrumentation diagrams (P&IDs) are analyzed by a group of specialists during HAZOP studies in order to find out the reasons and unfavorable results for all potential deviations from normal operation that could come out [33].

In order to ease the study, a system is divided into sections in a manner that the design purpose or function for each section can be sufficiently identified. The sections are probably small in reference to the system in complicated systems and those that the expected risk level is high, whereas usage of larger sections in uncomplicated systems and those that the expected level of risk is low will simplify the study [34].

In a HAZOP study, when guide words are implemented to the process parameters in every single part of the plant, deviation as the corresponding process variable is acquired (Figure 2.5) [33].

Figure 2.5. Basis of a HAZOP Study

In the beginning, HAZOP was developed to examine chemical processes, but has afterwards been advanced to other types of practices and also to complicated procedures and to software systems [32]. Example of usage areas are as follows [29], [34]:

- **Process HAZOP**

Process HAZOP is the initial approach that was originated in order to analyze process systems and plants.

- **Procedure HAZOP**

Review of procedures such as transportation of people, administrative works in different industries, offered organizational changes, checking and developing documents of instructions, and procedures for critical activities.

- **Software HAZOP**

Identification of possible errors in the development of software, including programmable electronic systems.

- **Human HAZOP**

Instead of technical failures, Human HAZOP is more focused on human errors.

HAZOP studies consist four basic steps as shown in Figure 2.6 [34]:

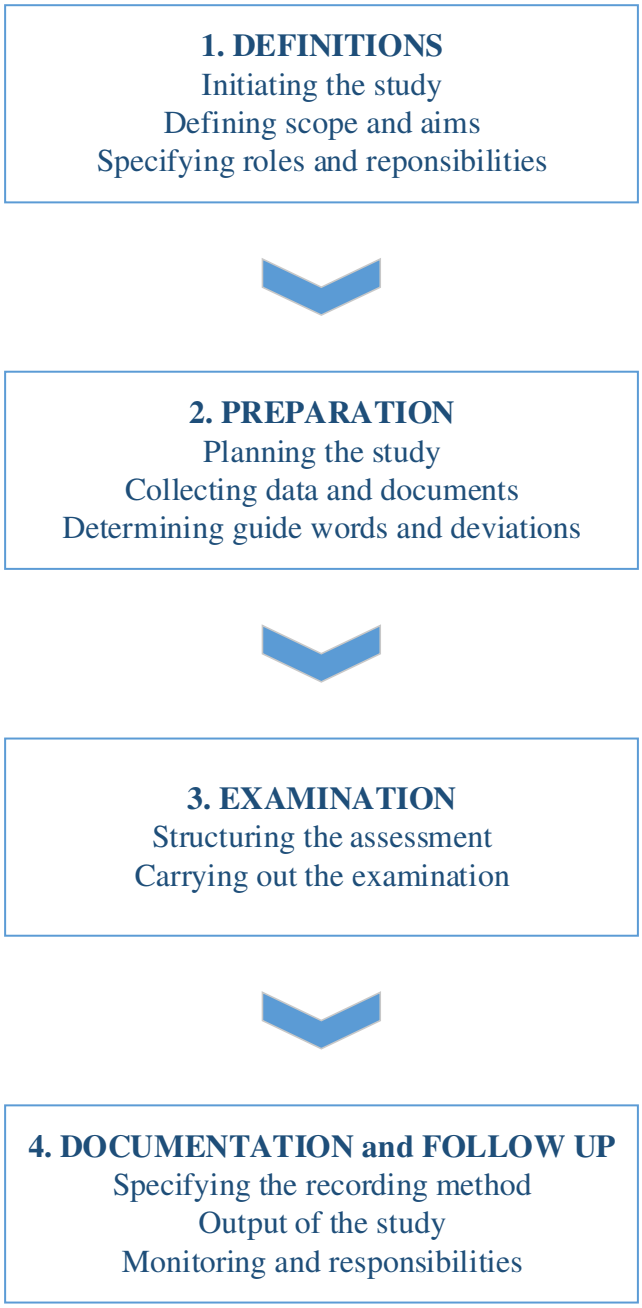

Figure 2.6. HAZOP Study Procedure

2.6.1. Process HAZOP

Before starting the HAZOP study, required information should be provided. For the Process HAZOP study, documents like process flow diagrams (PFDs), P&IDs, layout drawings, safety data sheets (SDS), operation and intervention procedures, emergency procedures, equipment, piping and instrumentation specifications should be available. A worksheet is usually used to document the results obtained from the HAZOP study. Worksheets may differ depending on the scope of the study and generally the following columns are included [29]:

- Reference number
- Study node
- Guide word
- Deviation
- Possible causes
- Possible consequences
- Existing barriers
- Proposed improvements
- Responsible
- Comments

An example of a Process HAZOP worksheet according to the flow sheet demonstrated in Figure 2.7 is shown in *Table 2.2* [29], [34].

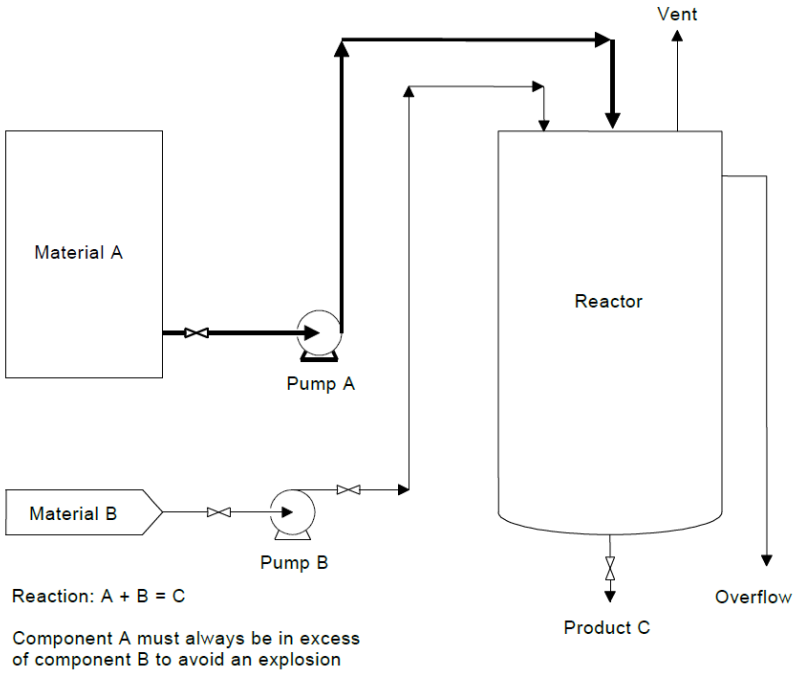

Figure 2.7. Simple Flow Sheet [34]

Table 2.2. *Process HAZOP Worksheet Example*

Study title: Example					Page: 1of 1		
Name:					Date: 12.03.2019		
Part considered:					Transfer line from tank A to reactor		
No	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Comments	Proposed improvements
1	No	No A	Tank A is empty	Explosion because of not flowing material A into the reactor	None	Unacceptable	An alarm can be installed on tank A in order to detect low-level
2	No	No transfer of A happens	Pump A is not running	Explosion	None	Unacceptable	Flow rate of A can be measured and a low flow alarm can be used, pump B can be stopped with an automated system when low flow of A happens.
3	As well as	Another material except A is present in the tank	Contaminated feed to tank	Cannot be estimated	Feeds of all tankers are controlled and analyzed before feeding	Acceptable	Operation procedure should be controlled
4	…						

2.6.2. Procedure HAZOP

Procedure HAZOP is used to determine hazards and reasons of troubles like operational or quality problems and loss of time by analyzing existing or planned work procedures. Procedure HAZOP focuses on either technical error of systems and human mistakes, and can be implemented to all series of activities [35].

In the Procedure HAZOP the same guide words can be used as in the Process HAZOP. Alternative guide words for Procedure HAZOP are indicated in *Table 2.3* [35].

Table 2.3. *Guide Words for Procedure HAZOP Method*

Guide words	**Meaning**
Unclear	Confusing written procedure, unclear responsibilities or not suitable for purpose
Step in wrong place	Actions will happen in incorrect order
Wrong action/wrong sequence	Incorrectly specified procedure activity
Incorrect/insufficient information	Controlled information before activity is specified wrongly or absent.
Step omitted	Step is forgotten, lacking or operator cannot fulfil all required steps
Step unsuccessful	Failed step
Interference effects	Activity is influenced by other effects like other activities carried out at the same time, same place
Not available/ not applicable/ not followed	No procedure is available or applicable to the activity or procedure not followed by the employees
Too few/ Too many	Number of employees is insufficient or needless for the activity
Wrong position	Incorrect position or movement exceeding limits
Power	Complete loss, partly lost
Above limitations	Hot weather

2.6.3. Human HAZOP

Human HAZOP is originated from conventional HAZOP method (Process HAZOP) and used for examination of human deviations while working and carrying out procedures [29], [36]. In Human HAZOP studies, the guide words used in process HAZOP method are used to analyze human duties [36].

The aims of Human HAZOP studies are to [29]:

- Specify all possible deviations that will happen during activities, their reasons, and the hazards linked with these deviations
- Determine the hazards requiring actions and specifying the solutions for solving the problems
- Check that the required actions are monitored
- Ensure employees are aware of hazards that they will face

Listing and specification of activities are the fundamentals of Human HAZOP. Each activity is examined in the same way as the nodes in the conventional Process HAZOP study. Human HAZOP studies are not based on a standard and various authors have built up their own group of guide words. The equivalent of Process HAZOP guide words that can be used in Human HAZOP studies are given in *Table 2.4* [29].

Table 2.4. *Human HAZOP Guide Words with Equivalent Process HAZOP Guide Words*

Process HAZOP Guide Words	**Human HAZOP Guide Words**
No	Not done
Less	Less than
More	More than
As well as	As well as
Other than	Other than, Repeated, Sooner than
Reverse	Later than
Part of	Part of

A dictionary of the guide words for a Human HAZOP study is given in *Table 2.5* [37].

Table 2.5. *Meanings of Human HAZOP Guide Words*

Guide word	**Meaning**
Not done	Not fulfilled activity
Repeated	Fulfilment of activity more times
Less	Fulfilment of activity with a smaller impact
More	Fulfilment of activity with a bigger impact
Earlier	Fulfilment of activity earlier
Later	Fulfilment of activity later
And also	Fulfilment of activity with another one concurrently
Reversed	Violation of sequence of activities
Other than	Fulfilment of an activity rather than requested one
Part	Fulfilment of only a part of activity

Human HAZOP has some advantages such that it is flexible, structured, and comprehensive and also simple and one who will study with Human HAZOP does not need to have thorough understanding of human reliability and cognitive psychology [29]. It is strengthened by checklists and attractive to engineers. On the other hand, Human HAZOP has some restrictions such that it can be time consuming and need significant effort [29].

An example of a Human HAZOP worksheet is shown in *Table 2.6* [29].

Table 2.6. *Example of a Human HAZOP Worksheet*

Study area: Section P1 Date:20.12.2018

Reference: Name:

No.	Guide word	Action (description)	Action error	Possible causes	Possible consequences	Comments	Proposed improvements
1	Other than	Close manual valve A	Wrong valve is closed	• Procedure error • Communication error • Valve marking inadequate • Lapse	Explosion		
2	…						

2.6.4. Multi-level HAZOP

Multi-level HAZOP method is originated to analyze all deviations and determine the necessary precautions to be taken for reducing risks where traditional methodologies are not sufficient. It was developed by considering conventional HAZOP and Human HAZOP concepts and has vertical and horizontal analysis.

In vertical analysis, sequence of steps of the procedures are examined in a hierarchical manner and in horizontal analysis, steps are examined at operator, control system, and plant/process levels [38].

For instance, in order to analyze the procedure where an operator is in charge of opening the main valve of a tank when the predetermined internal pressure is reached; operator, control system, and process levels can be analyzed as follows [38]:

- Internal pressure of the tank should be checked and "open" command should be given by the *operator*,
- Internal pressure should be displayed correctly and valve should be activated by the *control system*,
- Valve of the fluid filling line should initially be open and the physical conditions of the fluid and the tank should be appropriate at *process level*.

2.6.5. Improved HAZOP with Qualitative Risk Analysis

This method is used to evaluate the probability and severity of each scenario developed in the HAZOP study. By doing so, choosing the most important preventive measures for implementation is possible.
Titles in the worksheet of a HAZOP study with qualitative risk analysis is given in *Table 2.7* [37].

Table 2.7. *Example Worksheet of a HAZOP Study with Qualitative Risk Analysis*

Guide word	Deviation	Causes	Probability	Effects	Safety functions	Severity	Estimated risk	Preventive measure
No	No A	Tank A is empty	5	Explosion because of not flowing material A into the reactor	-	5		

2.6.6. Previous Human HAZOP Studies

Human HAZOP technique was used to analyze human failures in several industries. Some examples of implementations are given in this section.

In 2018, since the number of agricultural machinery accidents stayed high, and besides the lack of machinery, human factors were accounted as the large proportion of the causes of these accidents, Human HAZOP methodology was applied in combine harvesters in China. In the study, firstly, operation specifications were divided into nodes, and then guide words were applied to analyze human factors, causes, consequences, and existing barriers. Finally, further protective measures were recommended. As a result, it was seen that not to train employees before starting work, fatigue driving, poor safety awareness, poor operating environment, and not doing the maintenance timely are the causes of deviations. Study concluded that HAZOP analysis of human failures is a good way to solve the loss resulted from human deviations [39].

A study which was done in 2018, used Human HAZOP technique for identifying human errors in a flour company. In the study, potential human errors were analyzed and results showed that 85 of 144 determined errors (59.03%) were not-performing the task. It was indicated that main reasons of these errors are forgetfulness and negligence. It is followed by performing part of the task with 15.97% (23 of 144 errors). Negligence, fatigue, dissatisfaction with the job and having simultaneous jobs

were stated as the reasons of these errors. At the third place, late performance error is ranking with 7.64% (11 of 144 errors) and fatigue is indicated as the main cause. In conclusion, to minimize the probability of occurrence of human errors and their results; developing training programs, preparing checklists, defining instructions, and monitoring implementations were recommended [40].

Human factors were analyzed in an oil extraction plant in Portugal, where hexane is used as the main solvent to extract oil from vegetable seeds. In the industrial plant where the research was conducted, large tanks are used for storage of hexane and large tank trucks are bringing it periodically. Many sequential activities like arrival of truck, procedures of parking and preparation, unloading of solvent and transfer to tanks, and procedure of departures were analyzed. Human factors were analyzed by using Human-HAZOP methodology. As a result, bad communication, incorrect instructions, lack of information, presence of non-authorized people, smoking workers, poor housekeeping, and cleaning were identified as some of the critical failures. Finally, it was stated that with clearer instructions and better training, most of the human related failures can be prevented [41].

CHAPTER 3

APPLIED METHODOLOGY

3.1. Study Area

In this study, the services carried out in the parks, gardens, and green fields of municipalities were evaluated. A workplace which is responsible for landscaping and horticultural activities of a metropolitan municipality was selected for the examinations.

Six occupational safety specialists, three occupational physicians, and three health personnel are working at the company. There are 2000 employees including workers after retirement and additionally 41 employees from subcontractor companies. Seasonal workers are recruited by subcontractors mostly in summer season.

Before starting the study, a pre-interview was held with the occupational safety specialist of the selected workplace. Information about the planned work was given and necessary permissions were got. Afterwards, examinations were started with field visit to a park with 275,000 m^2 area and activities like lawn mowing, shrub pruning, flower and hedge planting were observed in terms of OHS. In addition, activities carried out in areas open to vehicular traffic including night works were observed. In these visits, activities such as tree staking, watering, and turf laying were examined. Landscaping and horticultural services were also monitored in parks with 640,000 m^2, 175,000 m^2 and 508,000 m^2 areas.

During the field visits, discussions were done with the occupational safety expert and photographs were taken where appropriate.

3.2. Implemented Method

In Turkey, for the risk assessment applications in landscaping and horticultural services, risk matrices and Fine-Kinney methods are generally used. In these methods, evaluations and risk scoring are subjected to the practitioner and because of the final risk score, some important risks may be missed.

In order to carry out human failure risk assessment, HSE (Health and Safety Executive, UK) recommends Human-HAZOP approach [42]. Landscaping and horticultural services includes mostly human-driven activities than automated ones. Therefore, HAZOP method was implemented to see the procedure and human focused hazards and risks in landscaping and horticultural services.

Firstly, for collecting data, field visits were done. After the field visits and examination of the activities, guide words were determined and given in *Table 3.1*.

Table 3.1. *Determined Guide Words for the Study*

Guide word	**Meaning**
Step omitted	Skipping steps while performing the activity
Position	Awkward placement which can lead to potential error, wrong position or movement exceeding limits
Safety	Personnel protection, hazards, regulation compliance
Lack of competence	Used for personnel
No information	Necessary information or procedure does not exist
Abnormal conditions	Unusual weather or working conditions

Deviations were detected by using the appropriate guide words for each activity. Then, examinations including possible causes and consequences of the deviations, existing barriers, and proposed improvements were recorded in the HAZOP worksheets given in Evaluations and Results section.

CHAPTER 4

EVALUATIONS AND RESULTS

4.1. Evaluation of Landscaping and Horticultural Services

Landscaping and horticultural activities in parks and areas open to vehicular traffic were examined in 4 main topics. These are green field services, cleaning services, construction and maintenance services, and auxiliary works. Evaluated services in this study are given in Figure 4.1.

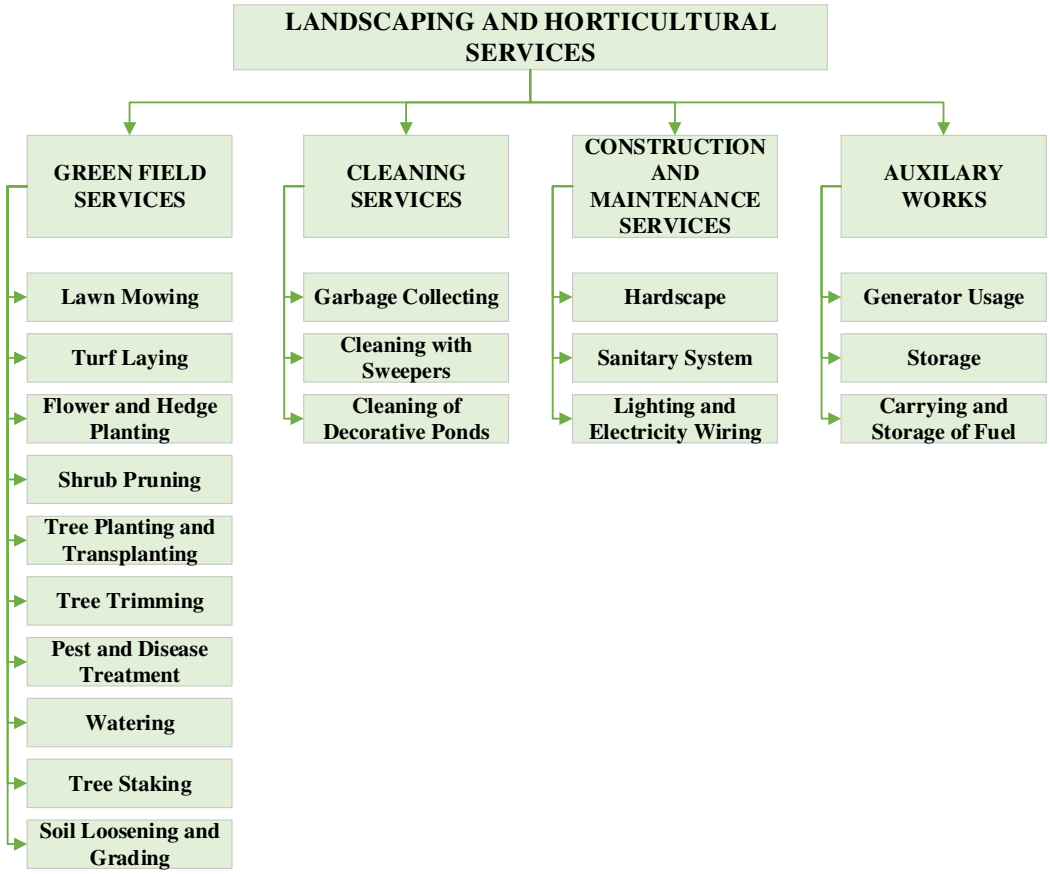

Figure 4.1. Services that are Evaluated in the Study

4.1.1. Green Field Services

Green field services in landscaping and horticultural works in municipalities were examined in ten topics.

4.1.1.1. Lawn Mowing Services

Lawn mowing activities are carried out in all areas of the municipality such as parks, gardens, and medians. The equipment like motor scythes, lawn mowers, and lawn tractors used in these activities are working with fuel.

In Figure 4.2, it is seen that when the worker took a break, the motor scythe and the lawn mower are left at random. This equipment can be used by unauthorized people.

Figure 4.2. Motor Scythe and Lawn Mower

Figure 4.3 shows an employee using motor scythe with safety eyewear, gloves, and a hat in order to be protected from sun. However, he is not wearing ear protector, the length of the motor scythe is not adjusted to worker's height and the working area is not closed to pedestrians. A flying object can injure a passer-by.

Figure 4.3. Usage of Motor Scythe

In Figure 4.4, an employee is picking up the mown grasses to plastic bags by bending down. The bags are collected and disposed with tractors. He is wearing hat to prevent from sun and protective gloves.

Figure 4.4. Picking up Mown Grasses

4.1.1.2. Turf Laying Services

Figure 4.5 shows turf laying activities. During turf laying, employees are working for a long time under the sun and by bending down. It was observed that the employees wear safety shoes and protective gloves and some of them wear hats.

Figure 4.5. Turf Laying

In sloping ground, wooden stakes are penetrated into soil in order to prevent movement of turfs after laying (Figure 4.6). Roll-on lawns are carried by employees to the working area.

Figure 4.6. Turf Laying in Sloping Ground

Turf laying is also done in areas open to vehicular traffic. In Figure 4.7, it is seen that the materials are also laying on the road and the working area is not closed. It is also seen that, traffic warning signs which are for safety and noticing the drivers are not used.

Figure 4.7. Preparation of Turf Laying on the Roadside

4.1.1.3. Flower and Hedge Planting Services

Flower boxes and hedges are transported with trucks to the area where flowering and hedge planting will be done. It was observed that the truck moves backwards on pedestrian area without audible and visual warning and closing working area. Boxes are lifted down by employees. Side hatches of truck are not fixed before starting the activity (Figure 4.8).

Figure 4.8. Lifting down the Flower Boxes

As can be seen from the Figure 4.9, employee is working on knees during planting flowers. Moreover, electric cables for lighting of parks are passing through the planting area. The authorities reported that mains voltage is used for lighting.

Figure 4.9. Flower Planting

Flowering and hedge planting activities are also carried out in areas open to vehicular traffic. It was observed that traffic warning signs are not used during the activity. As can be seen from Figure 4.10, flagging signaler is diverting the traffic without any warning signs.

Figure 4.10. Flagging Signaler at Median Flowering

During the activities done in areas open to vehicular traffic, employees are eating their meals at the working area. There may be infections because of biological hazards. In addition to this, after the activity is finished, employees are crossing the street without stopping traffic flow and taking necessary safety precautions. There are also various hazards during transportation of employees to working area. Workers can sometimes be transported even on the digger (Figure 4.11). Transportation is generally done with services and trucks.

Figure 4.11. Transportation of Workers

4.1.1.4. Shrub Pruning Services

Pruning shears and fuel-operated hedge trimmers are used in shrub pruning activities. As can be seen from Figure 4.12, employee is working by bending down and without wearing safety eyewear.

Figure 4.12. Shrub Pruning

In Figure 4.13 while hedge pruning, an employee is wearing hat for sun protection and safety eyewear to be protected from flying objects, however not wearing ear protector.

Figure 4.13. Hedge Pruning

4.1.1.5. Tree Planting and Transplanting Services

Tree saplings are carried with trucks to planting area. Sapling pots are lifted by employees and loaded to digger (Figure 4.14).

Figure 4.14. Lifting of Pots

Employees have difficulty while taking out saplings from pots because of their weight. It was observed that the employees are using safety footwear, however not using safety helmet and eyewear (Figure 4.15).

Figure 4.15. Taking out Saplings from Pots

Hand tools such as pickaxes and shovels are also used for planting trees. Soil grading is required in these activities. In Figure 4.16, employees are working near digger without wearing safety helmets and taking any precautions.

Figure 4.16. Tree Planting

For removal and planting of big trees, transplanting machines are used. It was seen that during tree removal, employees are not taking necessary safety precautions and standing near the transplanting machine (Figure 4.17).

Figure 4.17. Tree Transplanting

4.1.1.6. Tree Trimming Services

Employees are usually working at height during tree trimming activities. Generally, ladders and mobile elevating work platforms are used. It was observed that the employees are working with tree pruners on the ladder without taking any safety precautions and an employee is talking on the phone while trimming (Figure 4.18). Moreover, necessary personal protective equipment (PPE) are not used by employees.

Figure 4.18. Trimming of Trees

4.1.1.7. Pest and Disease Treatment Services

Pest and disease treatment is done with atomizer sprayers and sprayer tanks. It was observed that the employees do not have information about the hazards of the chemicals they are using and there is no safety data sheet (SDS) of the chemicals used in the area where the employee can access.

Figure 4.19. Pest Control

As can be seen from Figure 4.19, employee is working without wearing respiratory protective equipment.

Figure 4.20. Pest Control with Sprayer Tank

As can be seen from Figure 4.20, employee working with pest control sprayer tank is carrying out the activity at night when people are not around and wearing protective clothes, gloves and respiratory protective equipment.

4.1.1.8. Watering Services

Sprinkler irrigation systems and watering tankers are used in these services.

It was observed that while the water tanker moves slowly, the employee followed the tanker and could not communicate with the driver easily. In Figure 4.21, an employee on the tanker is seen. He is watering while the tanker is driven at a speed of approximately 20 km/h.

Figure 4.21. Watering with Tankers

Traffic cones are tied to watering tanker and moving with it (Figure 4.21). In addition, the road gets wet and slippery while watering is done.

4.1.1.9. Tree Staking Services

Tree staking is done to prevent the tree from bending due to wrong planting or wind and to ensure a balanced growth. During placing stakes into ground, employees use excessive force (Figure 4.22).

Figure 4.22. Placing Stakes into Ground

Figure 4.23 shows an employee penetrating stake into the soil with a hammer. Employee is working on the ladder without taking precautions. Another employee is holding the ladder and try to prevent falling.

Figure 4.23. Penetrating Stakes into Soil

4.1.1.10. Soil Loosening and Grading Services

Soil loosening machine is hard to control. In Figure 4.24, an employee who is using soil loosening machine is wearing safety footwear and gloves but not wearing safety eyewear.

Figure 4.24. Soil Loosening

It was observed that during soil grading at the median, employee was not wearing ear protector and seat belt. In addition, no traffic warning signs were used, during the activity in areas open to vehicular traffic (Figure 4.25).

Figure 4.25. Soil Grading

4.1.2. Cleaning Services

Cleaning services in landscaping and horticultural works in municipalities were examined in three topics.

4.1.2.1. Garbage Collecting with Trucks

Garbage collection in the parks is carried out with trucks (Figure 4.26). It was observed that the employee is hanging on the back of the truck while the truck is moving.

Figure 4.26. Garbage Collection

4.1.2.2. Cleaning of Parks with Driver Type Sweeping Machines

It was observed that these services are carried out in crowded places and during using driver type sweeping machines; employees are listening to music with ear buds and talking with phones.

Figure 4.27 shows an employee who is not wearing seat belt during loading of the sweeping machine to the vehicle after the activity is finished.

Figure 4.27. Loading of Sweeping Machine

4.1.2.3. Cleaning of Decorative Ponds

Cables for lighting and fountains are passing from the bottom of the ponds. Before starting cleaning of ponds, power is cut and as shown in Figure 4.28, cleaning is done with machines or manually. The floors of the ponds are slippery. After cleaning, ponds are filled with hoses.

Figure 4.28. Cleaning of Ponds

In order to prevent formation of moss, bacteria and microorganisms in the ponds; disinfections are done regularly.

4.1.3. Construction and Maintenance Services

These services were examined in three topics.

4.1.3.1. Hardscape Construction Services

Figure 4.29 shows an employee spreading mortar by bending down.

Figure 4.29. Mortar Spreading

For the pedestrian ways in parks, during stone block pavement and tile setting activities, employees are working on knees. Figure 4.30 shows employees working with protective gloves and hats but without safety eyewear.

Figure 4.30. Tile Setting

4.1.3.2. Maintenance of Sanitary Systems

Before the activities that are done in confined spaces (Figure 4.31), necessary gas measurements are done and work permit is given if the values are acceptable. However, there is no documentation for work permissions, so some activities can be carried out without work permit. In these cases, necessary gas measurements cannot be done.

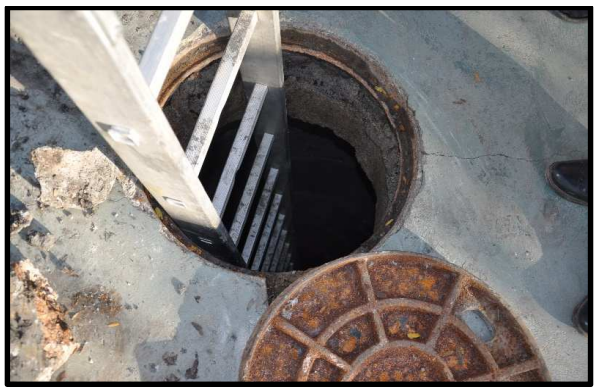

Figure 4.31. Working in Confined Spaces - Maintenance of Sanitary Systems

In Figure 4.32, it is seen that an employee is working with a bad posture and without safety eyewear.

Figure 4.32. Maintenance of Sanitary Systems

4.1.3.3. Maintenance of Lighting Elements and Electricity Wirings

Figure 4.33. Electric Pole Maintenance

During electric pole maintenance, activities are carried out by working at height. In Figure 4.33, an employee working at height without taking necessary precautions is seen.

Figure 4.34. Broken Lighting Element

Lighting elements with broken and sharp parts (Figure 4.34) can cause injuries and death. The same risks are present in Figure 4.35, which shows cables that can be directly touched by passers-by and cause electric shock.

Figure 4.35. Damaged Electric Pole

In Figure 4.36, a distribution board with open cover is seen. Although the employee cuts off electricity before starting work, it can be turned on by someone else without the employee's knowledge.

Figure 4.36. Distribution Board

4.1.4. Auxiliary Works

Auxiliary works were examined in three topics.

4.1.4.1. Generator Usage

For the activities that are carried out in parks, portable generators are used (Figure 4.37). Generators are transported to the working area with golf carts and it was observed that this is done without fastened and the area where generator operating is not closed to pedestrian traffic. Employees are working very close to the generators.

Figure 4.37. Generator Usage

4.1.4.2. Storage

There are many things in the storage areas such as machines, tools, cables, lighting elements and boxes. Figure 4.38 shows that the boxes are put on top of each other and the storage is untidy. Boxes and materials can fall over to employees and injuries may occur.

Figure 4.38. Storage Area

4.1.4.3. Carrying and Storage of Fuel

There are lots of machines used in landscaping and horticultural services. Most of them are operating with fuel. The fuel is stored in tanks and separate fuel tanks are available for both gasoline and diesel. Fuel is filled to cans for transporting them to the area where activity is carried out. It was observed that the storage areas are kept locked, however no labeling is done on the cans (Figure 4.39).

Figure 4.39. Fuel Storage

In Figure 4.40, fuel carried in plastic water bottle is left unattended near mowed grasses. This can cause a possible fire spread much faster.

Figure 4.40. Fuel in Plastic Water Bottle

4.2. Application of HAZOP Technique

HAZOP technique was conducted on the activities described in Chapter 4.1 in order to see the possible deviations of humans and procedures in landscaping and horticultural services. Determined guide words described in Chapter 2 were applied for each activity and deviations were discussed. Since some of the deviations were the same for the activities, they were not repeatedly given. Possible causes, possible consequences, existing barriers and proposed improvements were described for each deviation and given in following sections.

4.2.1. Application of HAZOP Technique to Green Field Services

Implementation of HAZOP method to humans and procedures in ten activities carried out in green field services are given in *Table 4.1*.

Table 4.1. *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
1	Step omitted	Cleaning and maintenance of machine/equipment before stopping	• Hurrying • Ignorance • Lack of knowledge	• Injuries • Amputation • Fatality	Training	• Ensuring that training covers the importance of stopping of the equipment before cleaning and maintenance • Placement of warnings on the equipment
2	Step omitted	Fueling is done before the machine/ equipment cools	• Hurrying • Ignorance • Lack of knowledge	• Fire • Injuries	Training	• Ensuring that training covers the importance of cooling of the equipment before fueling • A safeguard feature that prevents fuel lid from opening before the equipment cools • Placement of warnings on the equipment
3	Step omitted	Control of the equipment/machine is not done before activity	• Ignorance	• Injuries	Training	• Placement of warnings on the equipment • Training on importance of controlling equipment before activity

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
4	Step omitted	Fueling is done before the machine/equipment is stopped	• Hurrying • Ignorance • Lack of knowledge	• Fire • Injuries	Training	• Ensuring that training covers the importance of stopping of the equipment before fueling • A safeguard feature that prevents fuel lid from opening before the equipment stops • Placement of warnings on the equipment
5	Step omitted	Necessary traffic warning signs are not placed before starting activity in areas open to vehicular traffic	• Ignorance • Hurrying • Lack of knowledge • Signs not provided	• Injuries • Fatality	Training	• Necessary traffic warning signs should be provided for the activities in medians and roadsides • Training for using these warnings
6	Step omitted	Traffic flow is not stopped before walking across the street for the works done in medians	• Ignorance • Hurrying	• Injuries • Fatality	Training	• Training on importance of stopping traffic flow and walking across the street together

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
7	Step omitted	Procedure for flagging signaler is not followed	• Hurrying • Ignorance • Lack of knowledge	• Injuries • Fatality	Training	• Training and internal audits should be done more frequently • Procedures to be followed should be hand out to flagging signalers
8	Step omitted	Truck which carries flowers and hedges, moving on pedestrian area without closing working area	• Ignorance	• Injuries • Fatality	Training	• Preparation of procedure for flower and hedge planting activity and hand out them to the employees • Training and informing employees about the procedures
9	Step omitted	Lifting down flower boxes without fixing side hatches of truck	• Ignorance	• Injuries • Fatality	Training	• Training on importance of fixing the side hatches
10	Position	Machine/equipment left unattended by operator	• Ignorance	• Slip, trip and falls • Injuries	None	• Training on importance of not leaving machines/equipment unattended, possibility of usage by people around working area

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
11	Position	Working by bending down (i.e. while cleaning mowed grass, shrub pruning)	• Lack of knowledge	• Musculo-skeletal disorders	Equipment with adjustable height	• Training on adjustment of equipment and the importance of adjustments before starting to work, in addition, importance of taking sufficient breaks if bending down cannot be avoided
12	Position	Unsafe mowing on sloping areas	• Lack of knowledge	• Slip, trip, falls and tumble overs • Injuries • Fatality	Training	• Training on mowing lawns transversely with lawn mowers and vertically with lawn tractors on sloping areas in order to prevent falls and rollovers • Placement of warnings on the equipment
13	Position	Carrying of heavy roll-on lawns to working areas by employees	• Ignorance • Lack of equipment	• Injuries • Musculo-skeletal disorders	None	• Providing equipment for carrying • Training for safe handling of heavy items

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
14	Position	Working on knees while laying turf	• Nature of work	• Musculo-skeletal disorders	None	• Providing PPE for knees
15	Position	Carrying of heavy flower boxes and hedges by employees	• Ignorance • Lack of equipment	• Injuries • Musculo-skeletal disorders	None	• Providing equipment for carrying • Training for safe handling of heavy items
16	Position	Working on knees while planting flowers	• Nature of work	• Musculo-skeletal disorders	None	• Providing PPE for knees
17	Position	Carrying of heavy sapling pots and taking out heavy saplings from pots	• Lack of equipment	• Injuries • Musculo-skeletal disorders	None	• Providing equipment for carrying • Training for safe handling of heavy items

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
18	Position	Tree falls during working	• Ignorance • Inattention	• Injuries • Fatality	Training	• Training for working safely during planting and removal of trees
19	Position	Operating of digger and transplanting machine without closing working area	• Ignorance	• Injuries • Fatality	Training	• Ensure working area is closed before starting to operate • Training the employees on the risks
20	Position	Working on mobile elevating work platforms without physical barriers	• Ignorance	• Injuries • Fatality	Platforms with physical barriers	• Regular maintenance of the equipment
21	Position	Unsafe placement and usage of the ladder	• Ignorance	• Injuries	Training	• Usage of fixable ladders • Regular training on safe usage of ladders • Ladders with appropriate and strong supports

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
22	Position	Unsafe working at height	• Lack of knowledge • Ignorance	• Injuries • Fatality	Training, PPE	• Providing platforms with physical barriers for working at height • Providing necessary PPE like safety harnesses • Training on working safely at height
23	Position	Excessive force used by employee during tree staking	• Lack of equipment	• Musculo-skeletal disorders	None	• Providing equipment for tree staking in order not to use excessive force by employee
24	Safety	Passers-by while working	• Nature of work • No precautions	• Injuries because of flying objects, chemicals, machines	None	• Closing the working area to passers-by • Training on the risks because of flying objects especially while working with motor scythes • Training on the risks because of chemicals used during pest and disease control activities • Training on the risks of the machines used during activities

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
25	Safety	Employees behave unsafely	• Ignorance • Lack of knowledge	• Injuries	Training	• Training for safe working should be given more frequently
26	Safety	Necessary protective equipment do not used by employees	• Ignorance	• Injuries • Fatality	Reflective clothes, PPE	• All necessary PPE should be provided and employees should be trained to use them
27	Safety	Emergency stop button is not easily seen on the equipment	• No maintenance	• Injuries	None	• Carrying out maintenance regularly
28	Safety	Eating meal in the working area without being sure about personal hygiene	• Ignorance • No facility	• Infection because of biological hazards	None	• Training on importance of personal hygiene • Facilities should be provided for workers for personal hygiene (i.e. hand washing)

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
29	Safety	Unsafe transportation of workers	• Ignorance	• Injuries • Fatality	None	• Transportation of workers by safe shuttles and drivers who are taken OHS training
30	Safety	Sufficient lighting and warning is not done during night works	• Ignorance • Lack of equipment	• Injuries • Fatality	Training, Equipment	• Providing necessary lighting equipment for night works including lightened traffic warning signs • Providing reflective clothes to employees for night works
31	Safety	Carelessness of the operator	• Tiredness • Ignorance	• Injuries • Fatality	None	• Training on importance of the work being done • Training on importance of giving sufficient breaks
32	Safety	Truck moving on pedestrian area without audible and visual warnings	• Lack of warning equipment	• Injuries • Fatality	None	• Installing audible and visual warning equipment on trucks

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
33	Safety	Damaged cable ducts passing through the flower planting area	• Ignorance	• Electric shock • Fatality	None	• Placing warning signs where electric cables for lighting are passing • Regular maintenance
34	Safety	Flying objects while pruning	• Nature of work	• Injuries	PPE	• Providing necessary PPE to employees and train them on the importance of usage
35	Safety	Operator of transplanting machine/watering tanker is working without wearing seat belt	• Ignorance	• Injuries • Fatality	Training	• Regular training on importance of wearing seat belt

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
36	Safety	Chemical exposure of employees	• Ignorance • Lack of knowledge	• Skin, eye, respiratory system irritations • Poisoning • Fatality	Training, PPE	• Ensure training covers the hazards of the chemicals • Providing necessary PPE to employees
37	Safety	Employee is watering while tanker is moving	• Ignorance • Lack of knowledge	• Injuries • Fatality	Training	• Watering with automated systems, sprinkler systems • Attaching an equipment to the tanker so that no need to watering by an employee • Training on not to water while tanker is moving
38	Safety	Roads are getting wet and slippery while watering	• Ignorance • Inattention • Lack of knowledge	• Injuries • Fatality	Training	• Ensure training covers the importance of not to water roads, cars can slip and traffic accidents may happen • Regular maintenance of sprinkler systems

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
39	Lack of compe-tence	Employee with insufficient level of competence	• Lack of knowledge	• Injuries	Training	• Employee selection by regarding suitability to the work to be done • Training on equipment usage
40	No infor-mation	Necessary procedures for the activitie are not provided to employees	• Ignorance	• Injuries • Fatality	None	• Preparation of the procedures for the activities if they do not exist and hand out them to the employees • Training and informing employees about the procedures
41	No infor-mation	The necessary steps to be taken for the activities in areas open to vehicular traffic do not exist	• Ignorance	• Injuries • Fatality	None	• Preparation of the procedures for the activities in areas open to vehicular traffic and hand out them to the employees • Training and informing employees about the procedures

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
42	No information	No labeling of chemicals	• Ignorance • Lack of knowledge	• Irritations • Poisoning • Fatality	Training, Labeling of chemicals	• Training on labeling of chemicals • Providing appropriate containers for chemicals
43	No information	No SDS of chemicals or are not provided to employees	• Ignorance	• Irritations • Poisoning • Fatality	None	• Providing SDS to employees • Training on chemicals and SDS
44	Abnormal conditions	Working long time under sun and at hot weather	• Nature of work	• Heat stress • Dehydration • Fatality	Hats and long sleeved clothes	• Training on importance of drinking plenty of water and giving breaks more frequently and in the shade • Arranging working hours according to weather conditions for the summer season

Table 4.1 (cont'd). *HAZOP Study for Green Field Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
45	Ab-normal condi-tions	Working on wet and slippery ground	• Lack of knowledge • Ignorance	• Slips, trips and falls • Breakage of blades due to sticking of wet grass and injuries may happen	Training	• Training on not to mow wet grass and possible consequences of mowing wet grass • Slip resistant footwear
46	Ab-normal condi-tions	Working long time in cold weather	• Nature of work	• Illnesses	None	• Arranging working hours according to weather conditions • Providing thermally insulated clothes
47	Ab-normal condi-tions	Start of a heavy rain or hail during working	• Nature of work	• Illnesses • Injuries	None	• Controlling weather conditions for each day and arranging working hours according to it • Providing appropriate clothes

4.2.2. Application of HAZOP Technique to Cleaning Services

Implementation of HAZOP technique to humans and procedures in cleaning services which are garbage collection, cleaning of parks with driver type sweeping machines, and cleaning of decorative ponds are given in *Table 4.2*.

Table 4.2. *HAZOP Study for Cleaning Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
1	Step omitted	As a result of not controlling, pressurized water exit from hose during filling of the ponds	• Ignorance • Knowledge	• Injuries • Fatality	None	• Automated filling systems • Controlling water pressure before starting filling • Training
2	Step omitted	Power is not cut before cleaning	• Ignorance • Lack of knowledge	• Electric shock • Fatality	Training	• Ensuring that training covers the importance of cutting electricity before cleaning • Placement of warnings
3	Position	Hanging on the back of the garbage truck while the truck is moving	• Ignorance	• Injuries • Fatality	Training	• Ensuring training covers the safe working conditions

Table 4.2 (cont'd). *HAZOP Study for Cleaning Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
4	Position	Machine/ equipment left unattended by operator	• Ignorance	• Slip, trip and falls • Injuries	None	• Training on importance of not leaving machines and equipment unattended, possibility of usage by people around working area
5	Position	Working by bending down	• Lack of knowledge	• Musculo-skeletal disorders	Equipment with adjustable height	• Training on adjustment of equipment and the importance of adjustments before starting to work, in addition, importance of taking sufficient breaks if bending down cannot be avoided
6	Safety	Passers-by while working	• Nature of work • No precautions	• Irritation and poisoning because of chemicals • Injuries because of machines	None	• Closing the working area to passers-by • Training on the risks of chemicals used during disinfection of ponds • Training on the risks due to the machines used during activities

Table 4.2 (cont'd). *HAZOP Study for Cleaning Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
7	Safety	Employees behave unsafely	• Ignorance • Lack of knowledge	• Injuries	Training	• Training for safe working should be given more frequently
8	Safety	Necessary PPE is not used by employees	• Ignorance	• Injuries • Fatality	Reflective clothes, PPE	• All necessary PPE should be provided and employees should be trained to use them
9	Safety	Employees in the garbage truck without wearing seat belt	• Ignorance	• Injuries • Fatality	Training	• Regular training on importance of wearing seat belt
10	Safety	Biological hazard exposure of employees due to garbage/ pond cleaning	• Nature of work	• Infections • Illness	Training, PPE	• Providing necessary PPE to employees and train them on the importance of usage • Ensure training covers biological hazards

Table 4.2 (cont'd). *HAZOP Study for Cleaning Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
11	Safety	Eating meal without being sure about personal hygiene	• No facility	• Infections because of biological hazards	None	• Training on importance of personal hygiene • Facilities should be provided for workers for personal hygiene (i.e. hand washing, changing clothes)
12	Safety	Distractors like listening music with ear buds and talking with phone while using trucks/sweepers	• Ignorance • Lack of knowledge	• Injuries • Fatality	Training	• Ensuring training covers the safe working conditions
13	Safety	Damaged cable ducts in ponds	• Ignorance	• Electric shock • Fatality	Maintenance	• Placing warning signs where electric cables for lighting and fountains are passing • Regular maintenance

Table 4.2 (cont'd). *HAZOP Study for Cleaning Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
14	Safety	Chemical exposure of employees	• Ignorance • Lack of knowledge	• Skin, eye or respiratory system irritations • Poisoning • Injuries • Fatality	Training, PPE	• Ensure training covers the hazards of the chemicals • Providing necessary PPE to employees
15	Safety	Carelessness of the operator	• Tiredness • Ignorance	• Injuries • Fatality	None	• Training on importance of the work being done • Training on importance of giving sufficient breaks
16	Safety	Truck/ Sweeper moving backwards on pedestrian area without audible and visual warning	• Lack of warning equipment	• Injuries • Fatality	None	• Installing audible and visual warning equipment on trucks/ sweepers

Table 4.2 (cont'd). *HAZOP Study for Cleaning Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
17	Safety	Unsafe transportation of workers	• Ignorance	• Injuries • Fatality	None	• Transportation of workers by safe shuttles and drivers who are taken OHS training
18	Lack of competence	Employee with insufficient level of competence	• Lack of knowledge	• Injuries	Training	• Employee selection by regarding suitability to the work to be done • Training on equipment usage
19	No information	Necessary procedures for the activities are not provided to employees	• Ignorance	• Injuries • Fatality	None	• Preparation of the procedures for the activities if they do not exist and hand out them to the employees • Training employees about the procedures
20	No information	No labeling of chemicals	• Ignorance • Lack of knowledge	• Irritations • Poisoning • Fatality	Training, Labeling	• Training on labeling • Providing appropriate containers for chemicals

Table 4.2 (cont'd). *HAZOP Study for Cleaning Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
21	No information	No SDS of chemicals or are not provided to employees	• Ignorance	• Irritations • Poisoning • Injures • Fatality	None	• Providing SDS to employees • Training on chemicals and SDS
22	Abnormal conditions	Working on wet and slippery ground	• Nature of work	• Slips, trips and falls • Injuries • Fatality	Training, PPE	• Providing slip resistant footwear
23	Abnormal conditions	Working long time under sun and at hot weather	• Ignorance • Nature of work	• Heat stress • Dehydration • Fatality	Hats and long sleeved clothes	• Training on importance of drinking plenty of water and giving breaks more frequently and in the shade • Arranging working hours according to weather conditions for the summer season

Table 4.2 (cont'd). *HAZOP Study for Cleaning Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
24	Abnormal conditions	Working long time in cold weather	• Nature of work	• Illnesses	None	• Arranging working hours according to weather conditions • Providing thermally insulated clothes
25	Abnormal conditions	Start of a heavy rain or hail during working	• Nature of work	• Illnesses • Injuries	None	• Controlling weather conditions for each day and arranging working hours according to it • Providing appropriate clothes

4.2.3. Application of HAZOP Technique to Construction and Maintenance Services

Implementation of HAZOP technique to humans and procedures in construction and maintenance services which are hardscape construction, maintenance of sanitary systems, and maintenance of lighting elements and electricity wirings are given in *Table 4.3*.

Table 4.3. *HAZOP Study for Maintenance and Construction Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
1	Step omitted	Control of the hand tools is not done before activity	• Ignorance	• Injuries	Training	• Training on importance of controlling hand tools before and after the activity and not to use damaged tools
2	Step omitted	Employee starts working in confined spaces before necessary gas measurements are done	• Lack of knowledge • Ignorance	• Poisoning • Fatality	Measure-ments, Work permit, Training	• Training on procedures of working in confined spaces • Written work permit system should be used
3	Step omitted	Electricity does not cut off and necessary controls are not done before starting maintenance of lighting elements and electricity wirings	• Ignorance • Lack of knowledge	• Electric shock • Injuries • Fatality	Training	• Ensure training covers importance of cutting off electricity before starting maintenance of lighting elements and electricity wirings • Preparing procedures that covers all steps

Table 4.3 (cont'd). *HAZOP Study for Construction and Maintenance Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
4	Step omitted	Distribution board cover is left open	• Ignorance • Lack of knowledge	• Electric shock • Injuries • Fatality	Training	• Preparation of procedure for maintenance of lighting elements and electricity wirings and hand out them to the employees • Training on procedures
5	Position	Machine/ equipment left unattended by operator	• Ignorance	• Slip, trip and falls • Injuries	None	• Training on importance of not leaving machines and equipment unattended, possibility of usage by people around working area
6	Position	Working on knees during hardscape construction	• Nature of work	• Musculo-skeletal disorders	PPE	• Providing PPE for knees • Stone block paver and curb laying machines can be used

Table 4.3 (cont'd). *HAZOP Study for Construction and Maintenance Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
7	Position	Working by bending down or with a bad posture during hardscape construction and maintenance activities	• Lack of equipment	• Musculo-skeletal disorders	None	• Providing equipment like mortar spreaders with adjustable height • Training on importance of taking sufficient breaks if bending down or bad postures cannot be avoided
8	Position	Unsafe placement and usage of the ladder	• Ignorance	• Injuries • Fatality	Training	• Usage of fixable ladders • Regular training on safe usage of ladders • Ladders with appropriate and strong supports
9	Position	Mobile elevating work platforms without physical barriers	• Ignorance	• Injuries • Fatality	Platforms with physical barriers	• Regular maintenance of the equipment

Table 4.3 (cont'd). *HAZOP Study for Construction and Maintenance Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
10	Safety	Passers-by while working	• Nature of work • No precautions	• Injuries because of machines and etc.	None	• Closing the working area to passers-by • Training on the risks because of flying objects • Training on chemicals and electrical risks • Training on the risks of the machines used during activities
11	Safety	Employees behave unsafely	• Ignorance • Lack of knowledge	• Injuries	Training	• Training for safe working should be given more frequently
12	Safety	Necessary PPE is not used by employees	• Ignorance	• Injuries • Fatality	Reflective clothes, PPE	• All necessary PPE should be provided and employees should be trained to use them

Table 4.3 (cont'd). *HAZOP Study for Construction and Maintenance Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
13	Safety	Flying objects during construction and maintenance activities	• Nature of work	• Injuries	PPE	• Providing necessary PPE to employees and train them on the importance of usage
14	Safety	Unsafe usage of hand tools	• Lack of knowledge • Ignorance	• Injuries	Training	• Training on safe usage of hand tools
15	Safety	Chemical exposure of employees	• Ignorance • Lack of knowledge	• Skin, eye or respiratory system irritations • Poisoning	Training, PPE	• Ensure training covers the hazards of the chemicals • Providing necessary PPE to employees
16	Safety	Damaged electric poles and cables	• Ignorance	• Electric shock • Fatality	Maintenance	• Regular maintenance and control

Table 4.3 (cont'd). *HAZOP Study for Construction and Maintenance Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
17	Safety	Broken and sharp lighting elements	• Ignorance • Lack of maintenance and inspections	• Injuries	Mainte-nance	• Regular inspections and maintenance
18	Safety	Eating meal without being sure about personal hygiene	• No facility	• Infections because of biological hazards • Poisoning because of chemicals	None	• Training on importance of personal hygiene • Facilities should be provided for workers for personal hygiene (i.e. hand washing, changing clothes)
19	Safety	Unsafe transportation of workers	• Ignorance	• Injuries • Fatality	None	• Transportation of workers by safe shuttles and drivers who are taken OHS training

Table 4.3 (cont'd). *HAZOP Study for Construction and Maintenance Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
20	Safety	Insufficient lighting during works in confined spaces	• Ignorance • Lack of equipment	• Injuries	Lighting equip-ment	• Providing equipment that supplies sufficient lighting • Training on importance of sufficient lighting during works in confined spaces
21	Lack of compe-tence	Employee with insufficient level of competence	• Lack of knowledge	• Injuries	Training	• Employee selection by regarding suitability to the work to be done • Training on equipment usage
22	No infor-mation	Necessary procedures for the activities are not provided to employees	• Ignorance	• Injuries • Fatality	None	• Preparation of the procedures for the activities if they do not exist and hand out them to the employees • Training and informing employees about the procedures

Table 4.3 (cont'd). *HAZOP Study for Construction and Maintenance Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
23	No information	No labeling of chemicals	• Ignorance • Lack of knowledge	• Irritations • Poisoning • Fatality	Training, Labeling chemicals	• Training on labeling of chemicals • Providing appropriate containers for chemicals
24	No information	No SDS of chemicals or are not provided to employees	• Ignorance	• Irritations • Poisoning • Fatality	None	• Providing SDS to employees • Training on chemicals and SDS
25	Abnormal conditions	Working long time under sun and at hot weather	• Ignorance • Nature of work	• Heat stress • Dehydration • Fatality	Hats and long sleeved clothes	• Training on importance of drinking plenty of water and giving breaks more frequently and in the shade • Arranging working hours according to weather conditions for the summer season

Table 4.3 (cont'd). *HAZOP Study for Construction and Maintenance Services*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
26	Abnormal conditions	Working long time in cold weather	• Nature of work	• Illnesses	None	• Arranging working hours according to weather conditions • Providing thermally insulated clothes
27	Abnormal conditions	Start of a heavy rain or hail during working	• Nature of work	• Illnesses • Injuries	None	• Controlling weather conditions for each day and arranging working hours according to it • Providing appropriate clothes

4.2.4. Application of HAZOP Technique to Auxiliary Works

Implementation of HAZOP method to humans and procedures in auxiliary works are given in *Table 4.4*. Auxiliary works consist of generator usage, storage, and carrying and storage of fuel.

Table 4.4. *HAZOP Study for Auxiliary Works*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
1	Step omitted	Fueling is done before the generator cools	• Hurrying • Ignorance • Lack of knowledge	• Fire • Injuries	Training	• Ensuring that training covers the importance of cooling of the generator before fueling • A safeguard feature that prevents fuel lid from opening before the generator cools • Placement of warnings on the generator
2	Step omitted	Fueling is done before the generator is stopped	• Hurrying • Ignorance • Lack of knowledge	• Fire • Injuries	Training	• Ensuring that training covers the importance of stopping of the generator before fueling • A safeguard feature that prevents fuel lid from opening before the generator stops • Placement of warnings on the generator

Table 4.4 (cont'd). *HAZOP Study for Auxiliary Works*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
3	Step omitted	Not closing working area while the generator is operating	• Ignorance	• Electric shock • Injuries • Fatality	None	• Closing the working area to passers-by • Training on the risks that may arise while operating generators
4	Position	Transportation of generators without fastened	• Ignorance	• Fire • Injuries	Training	• Training on safe transportation of generators
5	Position	Carrying out activities too close to the generators	• Ignorance • Lack of knowledge	• Electric shock • CO poisoning • Fire • Injuries • Fatality	Training	• Training on safe usage of portable generators, not to use them in rain or wet conditions, in enclosed spaces, near flame producing or heat generating devices. • Providing PPE for noise if not possible to work far from generators

Table 4.4 (cont'd). *HAZOP Study for Auxiliary Works*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
6	Position	Untidy storage	• Ignorance	• Trip and falls • Injuries • Fatality	Training	• Provide adequate and safe storage areas • Training on safe storage • Inspecting storage areas
7	Position	Unfixed shelves and cabinets	• Ignorance	• Injuries • Fatality	None	• Fixing shelves and cabinets • Regular maintenance
8	Position	Taking materials stored at height unsafely	• Ignorance • Lack of equipment	• Injuries • Fatality	None	• Provide necessary equipment or machine like mobile elevating platforms for taking materials stored at height • Training on safe transportation of generators
9	Safety	Lifting heavy materials	• Ignorance • Lack of equipment	• Injuries • Musculo-skeleta disorders	None	• Providing equipment for carrying • Training for safe handling of heavy items

Table 4.4 (cont'd). *HAZOP Study for Auxiliary Works*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
10	Safety	Leakage of fuel	• Ignorance	• Slip, trip and falls • Injuries	Mainte-nance	• Controlling generators before and after usage
11	Safety	Smoking near fuel tanks	• Ignorance	• Fire • Explosion • Fatality	Training	• Ensure training covers the risks of smoking near fuel tanks
12	Safety	Storing fuel in inappropriate containers like plastic water bottles	• Ignorance • Lack of knowledge	• Poisoning • Fatality	Training	• Ensure training covers the risks of storing and carrying fuel in inappropriate containers
13	Lack of compe-tence	Employee with insufficient level of competence	• Lack of knowledge	• Injuries	Training	• Employee selection by regarding suitability to the work to be done • Training on equipment usage

Table 4.4 (cont'd). *HAZOP Study for Auxiliary Works*

No.	Guide word	Deviation	Possible causes	Possible consequences	Existing barriers	Proposed improvements
14	No information	Necessary procedures for the activities are not provided to employees	• Ignorance	• Injury • Fatality	None	• Preparation of the procedures for the and hand out them to the employees • Training and informing employees about the procedures
15	No information	No labeling of fuel	• Ignorance • Lack of knowledge	• Irritations • Poisoning • Fatality	Training, Labeling	• Training on labeling • Providing appropriate containers for chemicals
16	No information	No SDS of fuels or not provided to employees	• Ignorance	• Irritations • Poisoning • Fatality	None	• Providing SDS to employees • Training on chemicals and SDS
17	Abnormal conditions	Start of a heavy rain or hail during working	• Nature of work	• Electric shock • Injuries • Fatality	None	• Controlling weather conditions and arranging working hours • Providing appropriate clothes and equipment like canopies for generators

4.3. Results and Discussion

In order to see the possible deviations of humans and procedures in landscaping and horticultural services, HAZOP technique was conducted on the activities of green field services, cleaning services, construction and maintenance services, and auxiliary works which were examined and described in Chapter 4.1. The guide words *'step omitted'*, *'position'*, *'safety'*, *'lack of competence'*, *'no information'*, and *'abnormal conditions'* were applied for each activity and deviations were discussed. Since some of the deviations are the same for the activities, they were not repeatedly counted.

Total number of detected failures is 116 and the values according to services are given in Figure 4.41.

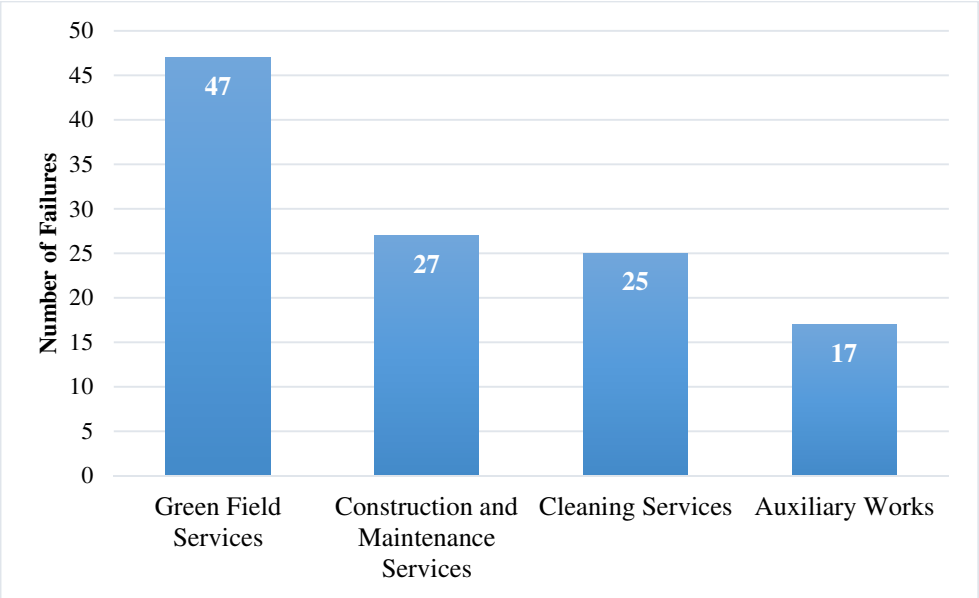

Figure 4.41. Number of Detected Failures in terms of Services

There are totally 47 deviations discussed for green field services. Number and percentage of detected failures due to humans and procedures are given in *Table 4.5*. The table indicates that with 31.9%, '*safety'* guide word which is used for describing concepts like employee protection, hazards, and regulation compliance has the highest rank. This is followed by '*position'* guide word which is used for describing deviations for awkward placement of equipment/machine, wrong positions, movement exceeding limits with 29.8%. They are followed by '*step omitted'* guide word which is used for describing deviations of skipping procedure steps while performing the activity with 19.1%. '*No information'* guide word which describes lack of necessary information and procedure and '*abnormal condition'* guide word which describes unusual weather and working conditions has the same value as 8.5% of total failures. '*Lack of competence'* guide word which is used for employees not having required qualification of the work being done has the lowest rank with 2.1%.

Table 4.5. *Number and Percentage of Detected Failures in Green Field Services*

Guide word	**Concept**	**Number of failures**	**Percentage of Failure (%)**
Safety	Employee protection, hazards, regulation compliance	15	31.9
Position	Awkward placement, wrong position or movement exceeding limits	14	29.8
Step omitted	Skipping steps of an activity's procedure	9	19.1
No information	Necessary information/procedure does not exist	4	8.5
Abnormal condition	Used for unusual weather or working conditions	4	8.5
Lack of competence	Used for personnel	1	2.1

Totally 25 deviations were determined in cleaning services. Number and percentage of detected failures are given in *Table 4.6*. As it is seen from the table, '*safety'* guide word which is used for describing concepts like employee protection, hazards, and regulation compliance has the highest rank with 48% and it is followed by '*abnormal condition'* guide word which describes unusual weather and working conditions, with 16%. '*No information'* guide word which describes lack of necessary information and procedure and '*position'* guide word which is used for describing deviations for awkward placement of equipment/machine, wrong positions, movement exceeding limits has the same value as 12% of total failures. They are followed by '*step omitted'* guide word which is used for describing deviations of skipping procedure steps while performing the activity with 8%. '*Lack of competence'* guide word which is used for employees not having required qualification of the work being done has the lowest rank with 4%.

Table 4.6. *Number and Percentage of Detected Failures in Cleaning Services*

Guide word	**Concept**	**Number of failures**	**Percentage of Failure (%)**
Safety	Employee protection, hazards, regulation compliance	12	48
Abnormal condition	Used for unusual weather or working conditions	4	16
Position	Awkward placement, wrong position or movement exceeding limits	3	12
No information	Necessary information/procedure does not exist	3	12
Step omitted	Skipping steps of an activity's procedure	2	8
Lack of competence	Used for personnel	1	4

There are 27 deviations discussed for construction and maintenance services. As can be seen from *Table 4.7* with 40.7%, '*safety'* guide word which is used for describing concepts like employee protection, hazards, and regulation compliance has the highest rank. This is followed by '*position'* guide word which is used for describing deviations for awkward placement of equipment/machine, wrong positions, movement exceeding limits with 18.5%. They are followed by '*step omitted'* guide word which is used for describing deviations of skipping procedure steps while performing the activity with 14.8%. '*No information'* guide word which describes lack of necessary information and procedure and '*abnormal condition'* guide word which describes unusual weather and working conditions has the same value as 11.1% of total failures. '*Lack of competence'* guide word which is used for employees not having required qualification of the work being done has the lowest rank with 3.7%.

Table 4.7. *Number and Percentage of Detected Failures in Construction and Maintenance Services*

Guide word	**Concept**	**Number of failures**	**Percentage of Failure (%)**
Safety	Employee protection, hazards, regulation compliance	11	40.7
Position	Awkward placement, wrong position or movement exceeding limits	5	18.5
Step omitted	Skipping steps of an activity's procedure	4	14.8
No information	Necessary information/procedure does not exist	3	11.1
Abnormal condition	Used for unusual weather or working conditions	3	11.1
Lack of competence	Used for personnel	1	3.7

There are 17 deviations discussed for auxiliary works. As can be seen from *Table 4.8* with 35.3%, '*position'* guide word which is used for describing deviations for awkward placement of equipment/machine, wrong positions, movement exceeding limits has the highest rank. This is followed by '*safety'* guide word which is used for describing concepts like employee protection, hazards, and regulation compliance, '*step omitted'* guide word which is used for describing deviations of skipping procedure steps while performing the activity and '*No information'* guide word which describes lack of necessary information and procedure with 17.6%. '*Abnormal condition'* guide word which describes unusual weather and working conditions and '*lack of competence'* guide word which is used for employees not having required qualification of the work being done comes next with 5.9%.

Table 4.8. *Number and Percentage of Detected Failures in Auxiliary Works*

Guide word	**Concept**	**Number of failures**	**Percentage of Failure (%)**
Position	Awkward placement, wrong position or movement exceeding limits	6	35.3
Safety	Employee protection, hazards, regulation compliance	3	17.6
Step omitted	Skipping steps of an activity's procedure	3	17.6
No information	Necessary information/procedure does not exist	3	17.6
Abnormal condition	Used for unusual weather or working conditions	1	5.9
Lack of competence	Used for personnel	1	5.9

Figure 4.42 shows number of discussed deviations (stated as failures) for all examined activities according to guide words and Figure 4.43 shows the percentage values.

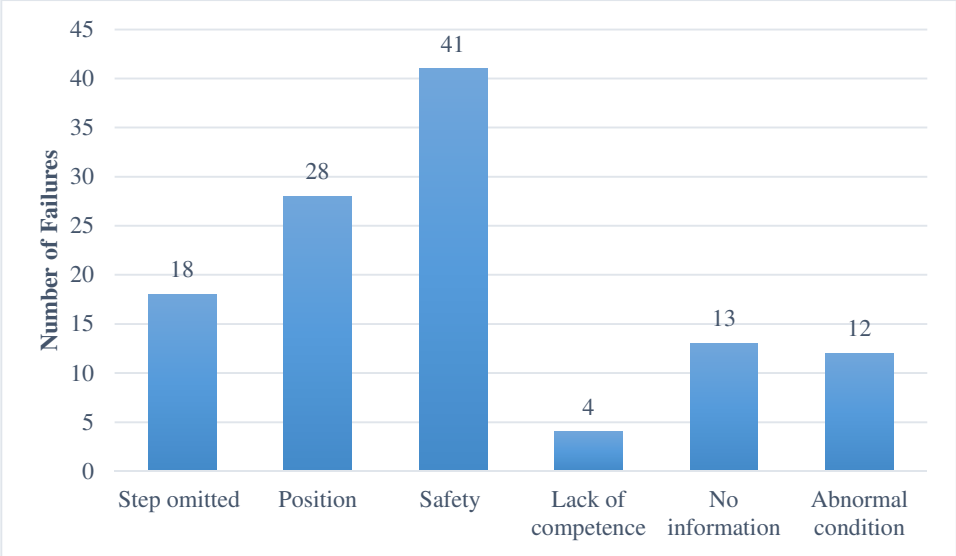

Figure 4.42. Number of Failures in terms of Guide Words

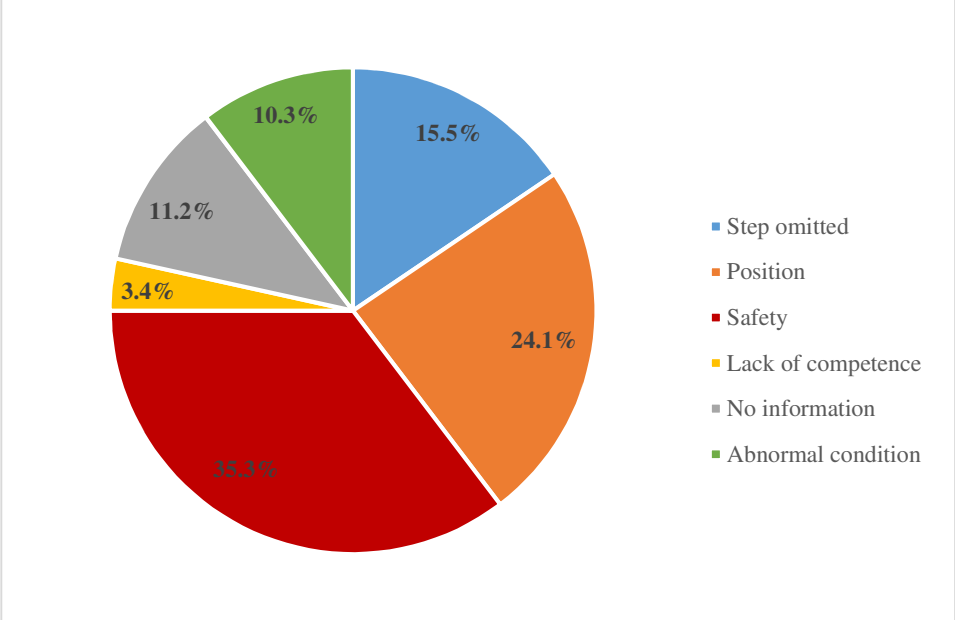

Figure 4.43. Percentage Values of Detected Failures in terms of Guide Words

Number of failures detected by applying '*safety'* guide word has the highest score with 41 out of 116 (35.3%). This shows, failures resulted from the following factors, have the highest value:

- Unawareness of chemical, electrical, and biological hazards
- Unsafe behaviors of employees
- Noncompliance of workplace regulations

Number of failures detected by applying *'position'* guide word has the second highest score with 28 out of 116 (24.1%). This shows, failures resulted from the following factors have the second highest value:

- Bad working positions/postures and heavy lifting
- Unsafe working conditions like heights, too close to generators
- Awkward placements like unattended left equipment/machine, unfixed shelves, untidy storages

Number of failures detected by applying *'step omitted'* guide word which indicates that the employee skips the necessary step/steps of an activity's procedure takes the third place with 18 out of 116 (15.5%).

At the fourth place, *'no information'* guide word is ranking with 13 out of 116 (11.2%) and indicates that necessary information like activities' procedures, safety data sheets of chemicals is lack.

'Abnormal conditions' guide word which shows the failures because of unusual weather or working conditions like working long time under sun, unexpected heavy rain, and wet and slippery ground is ranking as the fifth with 12 out of 116 (10.3%).

'Lack of competence' guide word which is used for employees not having required qualification of the work being done is ranking as the last with 4 out of 116 (3.4%). Competency of the employees is very important but generally, selection of employees is done by considering the qualifications. In addition, training on performing of activities and equipment/machine usage are given before starting working.

CHAPTER 5

CONCLUSIONS

HAZOP technique was conducted on the activities of green field services, cleaning services, construction and maintenance services, and auxiliary works to see possible deviations of humans and procedures in landscaping and horticultural services. The guide words *'step omitted'*, *'position'*, *'safety'*, *'lack of competence'*, *'no information'*, and *'abnormal conditions'* were applied for each activity and deviations were discussed.

Totally 116 failures were determined for all examined activities. 47 of them are in green field services, 25 of them are in cleaning services, 27 of them are in construction and maintenance services, and 17 of them are in auxiliary works. Most of the activities in landscaping and horticultural services are carried out in green field services. Moreover, the activities which are performed in areas open to vehicular traffic are in these services. Therefore, the highest number of discussed deviations is in green field services.

Number of deviations discussed by applying *'safety'* guide word which is used for describing concepts like employee protection, hazards, and regulation compliance has the highest score among others (35.3%). This shows that unsafe behaviors of employees, noncompliance of workplace regulations, and unawareness of chemical, electrical, and biological hazards cause the maximum number of failures among other factors.

This is followed by *'position'* guide word (24.1%) which shows failures resulted from bad working positions/postures, heavy lifting, unsafe working conditions (e.g. working at heights, too close to generators), and awkward placements (e.g. unattended left equipment/machine, untidy storages).

These are followed by failures because of skipping necessary steps of an activity's procedure with 15.5%. There are also deviations resulted from lack of information like procedures of activities and safety data sheets of chemicals with 11.2% and unusual weather and working conditions like working long time under sun, unexpected heavy rain and wet and slippery ground with 10.3%. Number of detected failures due to employees not having required qualification of the work being done is ranking as the last one (3.4%).

CHAPTER 6

RECOMMENDATIONS AND FUTURE STUDIES

For future studies in landscaping and horticultural services, first of all, appropriate training programs for raising awareness of workers on working safely, effects of possible hazards that will arise during performing activities, and importance of compliance of workplace regulations should be developed. Strengthening the training on performing of activities, equipment/machine usage, and PPE usage is also essential. Received training should be updated and implementations should be monitored frequently.

Importance of keeping the working area organized, encouraging times for resting, avoiding tiredness, and carelessness at work should be talked in daily safety moments.

Procedures for activities should be written clearly. Checklists could be prepared according to the procedures in order not to skip any step.

For reducing musculoskeletal disorders due to bad working postures and heavy lifting, machines and equipment with adjustable height and also mechanical lifting devices like skid-steer loaders and forklifts, and manual lifting equipment like dollies and hand trucks should be provided.

This study could be taken as a reference and further developed to use in other landscaping and horticultural workplaces for assessing risks caused by human and procedure failures.

This analysis could also be improved by integrating with other risk assessment methods.

REFERENCES

[1] MoLLS, “Occupational Healh and Safety Law No. 6331,” 2012.

[2] MoLLS, “Communiqué on Occupational Health and Safety Hazard Classes,” 2012.

[3] Republic of Turkey Social Security Institution, “SSI Annual Statistics.” [Online]. Available: http://www.sgk.gov.tr/wps/portal/sgk/tr/kurumsal/istatistik/sgk_istatistik_yillikari. [Accessed: 07-Jun-2019].

[4] United Nations, “International Standard Industrial Classification of All Economic Activities (ISIC), Rev.4,” 2008.

[5] Eurostat, “Statistical Classification of Economic Activities in the European Community (NACE), Rev. 2,” 2008.

[6] OSHA, “Landscape and Horticultural Services.” [Online]. Available: https://www.osha.gov/SLTC/landscaping/hazards.html. [Accessed: 07-Apr-2019].

[7] RHS, “Trees: Staking.” [Online]. Available: https://www.rhs.org.uk/advice/profile?pid=208. [Accessed: 07-Apr-2019].

[8] OSHA, “Confined Spaces.” [Online]. Available: https://www.osha.gov/SLTC/confinedspaces. [Accessed: 12-Apr-2019].

[9] M. Yazıcı, “Safe Working In Confined Spaces,” vol. 48, no. 573, pp. 41–45, 2007.

[10] A. G. Atasoy and N. Eğri, “Occupational Health and Safety of the Activities in Confined Spaces,” 2012.

[11] CCOHS, “Confined Space.” [Online]. Available: https://www.ccohs.ca/oshanswers/hsprograms/confinedspace_intro.html. [Accessed: 12-Apr-2019].

[12] IACS, “Confined Space Safe Practice (Rev. 3),” London, 2018.

[13] NASD, “Dangers of Heat Stress.” [Online]. Available: http://nasdonline.org/53/d001633/dangers-of-heat-stress.html. [Accessed: 20-

Apr-2019].

[14] NIOSH, “Cold Related Illnesses.” [Online]. Available: https://www.cdc.gov/niosh/topics/coldstress/coldrelatedillnesses.html. [Accessed: 15-Aug-2019].

[15] OSHA, “Cold Stress Guide.” [Online]. Available: https://www.osha.gov/SLTC/emergencypreparedness/guides/cold.html. [Accessed: 15-Aug-2019].

[16] A. J. Mauschbaugh, “Just How Safe Is Your Garden Center?,” 2006.

[17] “Civic Assets and Infrastructure Management and Maintenance.” [Online]. Available: https://www.citywide.com.au/services. [Accessed: 02-May-2019].

[18] “Pest Insect and Disease Management.” [Online]. Available: https://www.citywide.com.au/services-old/arboriculture-trees/pest-disease-management. [Accessed: 02-May-2019].

[19] “Tree Auditing.” [Online]. Available: https://www.citywide.com.au/services-old/arboriculture-trees/tree-auditing. [Accessed: 05-May-2019].

[20] “Tree Trunk Injections.” [Online]. Available: https://www.naturalwaylawn.com/tree/injections/. [Accessed: 02-May-2019].

[21] Australian Government Vocational Education and Training, “Certificate II in Parks and Gardens.” [Online]. Available: https://training.gov.au/Training/Details/AHC20616. [Accessed: 05-Jun-2019].

[22] Australian Government Vocational Education and Training, “Certificate III in Parks and Gardens.” [Online]. Available: https://training.gov.au/Training/Details/AHC31016. [Accessed: 05-Jun-2019].

[23] Australian Government Vocational Education and Training, “Certificate IV in Parks and Gardens.” [Online]. Available: https://training.gov.au/Training/Details/AHC40516. [Accessed: 05-Jun-2019].

[24] “Parks and Gardens Jobs and Qualifications.” [Online]. Available: http://www.ruralcareers.net.au/parks-and-gardens/. [Accessed: 05-Jun-2019].

[25] California Census of Fatal Occupational Injuries, “Fatal Occupational Injuries in California between 2013-2017,” 2018.

[26] Singapore Government Ministry of Manpower, “Workplace Safety and Health

Report," 2018.

[27] US Department of Labor Bureau of Labor Statistics, "Injuries, Illnesses and Fatalities." [Online]. Available: https://stats.bls.gov/iif/oshwc/cfoi/cfoi-chart-data-2017.htm. [Accessed: 07-Jun-2019].

[28] US Department of Labor Bureau of Labor Statistics, "Number of nonfatal occupational injuries and illnesses involving days away from work by industry and selected natures of injury or illness." [Online]. Available: https://www.bls.gov/iif/oshwc/osh/case/cd_r1_2017.htm. [Accessed: 07-Jun-2019].

[29] M. Rausand, *Risk assessment : Theory, Methods, and Applications*. Wiley, 2011.

[30] K. Alverbro, B. Nevhage, and R. Erdeniz, "Methods for Risk Analysis," Stockholm, 2010.

[31] L. T. Ostrom and C. A. Wilhelmsen, *Risk Assessment: Tools, Techniques, and Their Applications*. Wiley, 2012.

[32] M. D. Holloway and C. Nwaoha, *Dictionary of Industrial Terms*. Wiley, 2013.

[33] F. I. Khan and S. A. Abbasi, *Risk Assessment in Chemical Process Industries*. New Delhi: Discovery Pub. House, 1998.

[34] *IEC 61882:2016 Hazard and Operability Studies (HAZOP studies)-Application guide (International Standard)*. IEC.

[35] S. Haugen and M. Rausand, "Risk Assessment - HAZOP Notes," Norwegian University of Science and Technology, Department of Production and Quality Engineering.

[36] M. V. Stringfellow, "Accident Analysis and Hazard Analysis for Human and Organizational Factors," Massachusetts Institute of Technology, 2010.

[37] L. Kotek and M. Tabas, "HAZOP study with qualitative risk analysis for prioritization of corrective and preventive actions," in *20th International Congress of Chemical and Process Engineering*, 2012.

[38] E. Cagno, F. Caron, and M. Mancini, "Risk analysis in plant commissioning: The Multilevel Hazop," *Reliab. Eng. Syst. Saf.*, vol. 77, no. 3, pp. 309–323, 2002.

[39] Z. Cao, S. Cao, X. Xu, T. Han, H. Guo, and Y. Cui, “HAZOP analysis of human factors in combine harvesters,” in *IOP Conference Series: Materials Science and Engineering*, 2018, vol. 439, no. 3.

[40] Z. S. Nezamodini, M. Abasi, Z. Mosavianasl, and B. Kouhnavard, “Application of Human Hazop Technique for Identifying Human Error in a Flour Company,” vol. 2, no. 3, pp. 170–177, 2018.

[41] C. Jacinto and P. Henriques dos Marques, “Human-HAZOP studies in the risk management of major accidents,” in *International Symposium on Occupational Safety and Hygiene*, 2015.

[42] HSE, “Inspectors Toolkit: Human factors in the management of major accident hazards,” 2005. [Online]. Available: http://www.hse.gov.uk/humanfactors/topics/toolkit.pdf. [Accessed: 16-Mar-2019].