PERFORMANCE ASSESSMENT OF A FACTORY LAYOUT DESIGN: HYBRID MULTI CRITERIA DECISION MAKING MODEL WITH AN APPLICATION IN THE ELEVATOR AND ESCALATOR COMPANY

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PERFORMANCE ASSESSMENT OF A FACTORY LAYOUT DESIGN: HYBRID MULTI CRITERIA DECISION MAKING MODEL WITH AN APPLICATION IN THE ELEVATOR AND ESCALATOR COMPANY

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Approval of the Graduate School of Business

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ABSTRACT

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BUSINESS ADMINISTRATION PH.D PROGRAM

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The facility layout problem was one of the main research topics in industrial engineering and operations management areas. There are many research papers in the literature, in which the majority of them were made about the modelling of the layout. The researchers developed many algorithms such as mathematical modelling, heuristics, metaheuristics, and simulation algorithms to constitute a layout. Although the evaluation process of a layout is as important as the constitution of it, the relevant literature has lack of studies examining the performance of it.

The evaluation of the layout performance is important, because the evaluation of the layout performance is, in fact, the evaluation of the performance of the operations. The evaluation of the performance of the layout should examine the main characteristics of the layouts. Therefore, the indices, in other words, the criteria, the sub-criteria, and the measurements have to be determined carefully in order to understand and reflect the main characteristics of the layout.

Within this context, this dissertation aims to present a new hybrid multi criteria decision-making model approach in order to assess the performance of the layout. With a systematic and very detailed literature review, the criteria, corresponding sub-criteria, and the corresponding measurements are determined.

There are three major contributions of this dissertation. Firstly, we have categorized the indices as Criteria, Sub-Criteria, and Measurement. Secondly, the criteria set are an extended set to fully describe the dimensions of the layout effectiveness. Finally, we have integrated four different MCDM techniques in a hybrid model for the performance assessment.

The application was conducted in an elevator and escalator manufacturing firm located in Maltepe, Menemen, Izmir. Five experts from the firm participated in the survey; the general manager, the operations manager, the vice operations manager, the member of the executive board, and the craft supervisor.

The model, which is called hybrid multi criteria decision-making (MCDM) model, consists of different MCDM techniques. Firstly, fuzzy Total Interpretive Structural Modelling (TISM) technique is applied in order to determine the relationships between a set of criteria. Then, fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) technique is employed to identify the causal relationships. In the next step, with the help of the output of the fuzzy DEMATEL method, inner-dependence matrix, fuzzy Analytical Network Process (ANP) technique is applied in order to determine the weights of sub-criteria. After determining the weights of the sub-criteria, the weights of corresponding measurements are found using fuzzy Analytical Hierarchy Process (AHP) technique. Thus, the structural causal relationship, the weights of sub-criteria, and the weights of the measurements are found. All found weights are multiplied with the performance scores of all measurements which are evaluated with a collective session, in order to find the overall performance assessment score. The sum of the performance scores gives the overall performance score which represents the level of efficiency and effectiveness of the layout.

Key Words: Layout, Facility Layout Problem, Performance Assessment, Multi Criteria Decision Making.

ÖZET

FABRİKA YERLEŞİM DÜZENİ TASARIMININ PERFORMANS DEĞERLENDİRMESİ: ASANSÖR VE YÜRÜYEN MERDİVEN FABRİKASIDNA MELEZ ÇOK KRİTERLİ KARAR VERME MODELİ UYGULAMASI

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Tesis yerleşim düzeni problemi, endüstri mühendisliği ve işlemler yönetimi alanlarının temel araştırma konularından bir tanesidir. Literatürde, çoğu tesis yerleşim problemi modellemesi olarak karşımıza çıkan birçok araştırma makalesi bulunmaktadır. Araştırmacılar, bir yerleşim düzeni yaratmak için matematiksel modelleme, sezgisel yöntemler, üst sezgisel yöntemler ve benzetim gibi algoritmalar geliştirmişlerdir. Bir yerleşim düzenin değerlendirme süreci onun yaratılması kadar önemli olmasına rağmen, konuyla alakalı olan literatür, yerleşim düzeni değerlendirmesini inceleme açısından eksikliklere sahiptir.

Bir yerleşim düzeninin değerlendirilmesi önemlidir, çünkü yerleşim düzeni değerlendirmesi aslında işlemlerin performansının değerlendirmesidir. Yerleşim düzeninin performansının değerlendirmesi yerleşim düzeninin temel özelliklerini incelemelidir. Bu yüzden, indeksler, diğer bir deyişle, kriterler, alt kriterler ve ölçümler, yerleşim düzeninin temel özelliklerini anlamak ve yansıtmak için dikkatlice belirlenmelidir.

Bu bağlamda, bu tez çalışması yeni bir melez çok kriterli karar verme modeli yaklaşımı ile yerleşim düzeninin performansını değerlendirmeyi amaçlamaktadır. Sistematik ve detaylı bir literatür taraması yoluyla, kriterler, buna buna bağlı olan alt kriterler ve ölçümler belirlenmiştir.

Bu tezin üç temel katkısı vardır. Birincisi, indeksler; kriterler, alt kriterler ve ölçümler olarak sınıflandırılmıştır. İkincisi, kriter seti yerleşim düzeni boyutlarının etkinliğini tam anlamıyla açıklamaktadır. Son olarak, performans değerlendirmesi için, melez modelde dört farklı çok kriterli karar verme tekniği kullanılmıştır.

Uygulama, Maltepe/Menemen/İzmir bölgesinde faaliyet gösteren bir asansör ve yürüyen merdiven fabrikasında gerçekleştirilmiştir. Firmadan, genel müdür, üretim müdür, üretim müdürü yardımcısı, yönetim kurulu üyesi ve usta başı olmak üzere 5 uzman ankete katılmıştır.

Melez çok kriterli karar verme tekniği model olarak adlandırılan model, farklı çok kriterli karar verme tekniklerinden oluşmaktadır. İlk olarak, kriterler arasında ilişkiyi belirlemek için bulanık Toplam Yorumlayıcı Yapısal Model tekniği uygulanmıştır. Daha sonra, kriterler arasındaki nedensel ilişkileri belirlemek için, bulanık Karar Verme Deneme ve Değerlendirme Laboratuvarı tekniği, uygulanmıştır. Bir sonraki aşamada, alt kriterlerin önem ağırlıklarını belirlemek amacıyla, bulanık Karar Verme Deneme ve Değerlendirme Laboratuvarı tekniğinin sonucunun, iç bağlılık matrisinin, yardımıyla bulanık Analitik Ağ Süreci tekniği uygulanmıştır. Alt kriterler önem ağırlıkları belirlendikten sonra, her bir alt kritere bağlı olan ölçümlerin önem ağırlıkları, bulanık Analitik Hiyerarşi Süreci kullanılarak bulunmuştur. Böylelikle, yapısal nedensel ilişkiler, alt kriterlerin ve ölçümlerin önem ağırlıkları bulunmuştur. Bulunan bütün önem ağırlıkları, toplam performans değerini bulmak amacıyla, kolektif seansta değerlendirilen ölçümlerin performans değerleri ile çarpılmıştır. Performans değerlerinin toplamı, firmanın etkinlik ve verimlilik düzeyini gösteren toplam performans değerini vermiştir.

Anahtar Kelimeler: Yerleşim Düzeni, Tesis Yerleşim Düzeni Problemi, Performans Değerlendirmesi, Çok Kriterli Karar Verme.

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Muhittin SAĞNAK

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CHAPTER 1: INTRODUCTION

When studying in different research projects as well as research papers, it has been clear that most companies suffer from their layouts. Most of them have inefficient layouts, and fail to measure their layouts' efficiency and the effectiveness. This gap motivated us to develop a specific approach for the measurement of the performance of the layout. This will be the first study to extensively review the literature, identify very detailed criteria set, and develop a measurement scale for the assessment of the performance of the layout.

1.1. EVOLUTION OF PRODUCTION SYSTEMS

1.1.1. HISTORY

Historically, the evolution of production systems is categorized in four major types, namely, ancient, feudal, European, and American systems (Sipper and Bulfin Jr., 1997).

Sumerian priests began to keep track of tax transactions, loans, and inventories in 5000 B.C., which can be agreed as the start date of ancient systems. Around 4000 B.C., when Egyptians had constructed the pyramids, it can be argued that they used the basic management principles, such as planning, organizing, and control. The Code of Hammurabi, around 1800 B.C., was the next important development, emphasizing the minimum wage and the management responsibility. Around 1500 B.C., the Hebrews designed positions for staff, and started to choose appropriate workers to assign tasks. Around 1100 B.C., the Chinese practiced the planning and organizing of labor specialization, and controlling the production with a fully-developed government system. The Greeks examined the labor specialization, and the Greek workers worked at the same speed with uniform motions around 350 B.C.

The emperor, the king, or the queen had the unique power in the Middle Ages, which corresponded to the beginning of feudal system. In the name of lords, the power was given to nobles to participate in the delegation of lands, and authority to the serfs. Until the middle of the 15^{th} century, the major production factors were land and labor. Family members worked at home as both the owners and the workers.

The Renaissance period can be agreed as the start date of the European system. In spite of the fact that the Renaissance period is recognized as a period of cultural development, especially in Italy, there were also developments in the production systems, such as double entry bookkeeping and cost accounting. Around 1700s, the Industrial Revolution which started in the British Isles, was the next major development. Necessary food was produced with more productive farming methods, using less land and labor force. Commonly, the control was in the owner of the land, and the incentives were in larger scale for improving the production. The "division of labor" concept was emphasized when Adam Smith published "An Inquiry into the Nature and Causes of the Wealth of Nations" in 1776. He stated that the tasks should be separated and the workers should be responsible for only one part of the task, a process called specialization. Charles Babbage supported this idea on his book, "On the Economy of Machinery and Manufactures" published in 1832. Expectedly, the market size increased through the specialization of labor. People started to depend on other people more as the idea of specialization became established. Mass production and mass markets evolved through the urbanization of society, which gained the habits of buying things and spending money.

The start date of American system was around 1800s, which can be corresponded to the development of modern lathe by Maudslay. The development of modern lathe gave rise to the machine tool industry, having large scale impacts on subsequent developments. Another development occurred across the Atlantic

Ocean in America. Eli Whitney invented the cotton gin, and encouraged manufacturing using jigs and fixtures with less-skilled workers. The convergence of interchangeable parts, specialization of labor, steam power, and machine tools resulted in the emergence of the American system, which was the precursor of mass production as we know it today (Sipper and Bulfin Jr., 1997). In 1903, Oldsmobile Motors had generated a non-moving assembly line, and consequently, their productivity increased ten times. In 1908, Cadillac disassembled three cars; the parts were intermixed, and then reassembled to demonstrate the interchangeability of the parts. In 1913, Ford created a moving assembly line in which an automobile was assembled in every two hours. Thus, $400 automobiles became a product for the masses. The assembly line was the logical outgrowth of specialization of labor and the use of capital to replace labor. Not all manufacturing shops became mass production facilities. Plants that made a variety of parts with low demand, or customized products remained the same (Sipper and Bulfin Jr., 1997).

1.1.2. MANAGEMENT THEORIES

Early management theories evolved in this environment, because operating systems were needed to meet increased production demands. As in many other historical developments, a beginning is hard to pinpoint. Many people contributed to the process, but Henry Towne was the pioneer. In 1886, he declared that shop management was at least as much important as engineering management (Sipper and Bulfin Jr., 1997).

Frederick Taylor, often called the father of scientific management, started as a common laborer at Midvale Steel, and held a variety of jobs, working his way through the ranks until he became chief plant engineer. From his work experience, Taylor knew improvement must start with the workers. He felt the solution was not to make them work harder, but to manage them better. Management should develop proper work methods, teach these to the workers, and see that the workers follow them. In his book, “The Principles of Scientific Management” (1911), he stated that purpose to provide simple examples of waste through inefficiency, and to show that the solution lies with better management, not extraordinary workers.

In addition, he wrote that the best management is a true science, based on well-defined laws, rules, and principles, applicable to all human endeavors and yielding astounding results (Sipper and Bulfin Jr., 1997).

As the scientific management concept became popular in United States, the effects of this trend were also felt in Europe. Henri Fayol (1984) was an engineer who later became managing director of a large mining company in France. Like Taylor, he identified the recent problems from the top down. According to him, the firms had six functions, namely, technical, commercial, financial, security, accounting, and managerial.

1.2. FOUR PROCESS STRATEGIES

A process (transformation) is an organization approach composed of a set of interconnected activities to transform resources into goods and services. The process strategy aims to construct a production process that satisfies the requirements of the customers and the specifications of the products. The selection of a process affects the cost and the quality of the products, flexibility, and efficiency (Heizer and Render, 2014).

There are three main characteristics that affect the selection of a production process. The companies have to give an answer to the following questions:

1. How much variety will the company have in its products or services?

2. What degree of equipment flexibility will the company need for its operations strategy?

3. How many products will the company have to produce (volume of output) (Stevenson, 2009)?

The type of a production process will change according to the answers of these questions. There are four types of production processes, each give different answers to three questions. Those production processes are 1) process focus, 2) product focus, 3) repetitive focus, 4) mass customization.

1.2.1. PROCESS FOCUS

Process focus, which is also called intermittent process, is the most popular production process, providing “low-volume, high-variety” products in job shops. The factories organized as process-focused facilities are arranged as departments, such as welding, grinding, etc. In an office, the departments might be operations, accounting/finance, and human resources; in hospital, emergency service, and polyclinics. The facilities are organized with regard to the equipment, and supervision. Since a high variety of products is processed, a high level of flexibility is demonstrated, as the materials are transported between departments. In a facility, not all products have to follow the same production sequences; therefore, each facility handles a variety of activities (Heizer and Render, 2014).

The distinctive characteristics of the process focus production process are as follows (Ureten, 2013).

- Low-volume, high-variety production,
- Irregular demand,
- Using general-purpose machinery,
- Handling the machinery with same functional features in the same area,
- Skilled workmen,
- High work-in-process, low raw material, and finished goods inventory,
- Flexible to fulfill the changing demand in terms of volume or variety.

Generally, variable costs are high, and the utilization rate is low in process-focused facilities. However, it is possible to improve them with computer-controlled machines by programming the tools of the machines, part movements, placing pieces to the machines, and material handling efforts (Heizer and Render, 2014).

1.2.2. PRODUCT FOCUS

Product focus, also called continuous process, is another popular production process, providing “high-volume, low-variety” products. The factories organized as product-focused facilities are arranged as product-oriented. In a facility, each product has to follow the same production sequences; therefore, each facility employs standardization. Glass and paper may be an example of products that are produced with a continuous run, i.e., product focus strategy.

The distinctive characteristics of the product focus production process are as follows (Ureten, 2013).

- High-volume, low-variety production,
- Regular and high demand,
- High capital investment,
- Same sequence of processes for each product in same machinery,
- Using special-purpose machinery,
- Usability of unskilled workmen,
- Low work-in-process, high raw material, and finished goods inventory.

Generally, the fixed costs are high, but the variable costs are low, therefore the utilization rate is also high in product-focused facilities. Such facilities have advantages of setting standards and maintaining the quality level inherently, because they are organized around a unique product.

1.2.3. REPETITIVE FOCUS

Repetitive process lies somewhere between process and product focus strategies. It includes modules which are defined as parts made up in advance in a continuous process. Repetitive focus production process is, in fact, comprised of an assembly line. It is commonly used for automobile and white appliances. It has less flexibility than the process focus, but more than product focus strategies (Heizer and Render, 2014).

Repetitive focus production process has less customizing characteristics compared to process focus, and more compared to product focus production processes. It can be referred as a semi-custom strategy, because the assembling process enables the product be specific to the customer. However, this specificity is because of an assembly process, rather than a process as a whole.

Repetitive focus production process includes the economic advantages of product focus, and custom advantage of process focus strategies (Heizer and Render, 2014).

1.2.4. MASS CUSTOMIZATION FOCUS

Mass customization production process is the rapid and low-cost transformation of materials into products that satisfy the unique customer requirements. Customization aims not only to provide a product variety, but also to fulfill specific customer desires. It provides a product variety with a cost of high-volume production. In other words, the variety of products, which is the main characteristics of a process focus, is produced with low variable costs, which are the main characteristics of a product focus production process (Heizer and Render, 2014).

The most important feature of the mass customization production process is the modular design, which requires a tight link between the organizational functions, namely, design, manufacturing, supply chain, and logistics. It also requires very efficient production planning, flexibility in personnel and equipment, and rapid throughput.

Toyota and Dell Computer may be considered as the leading examples for mass customization. For example, Toyota claimed to be able to deliver customized cars in 5 days (Heizer and Render, 2014).

Figure 1 represents the characteristics of the four types of production processes.

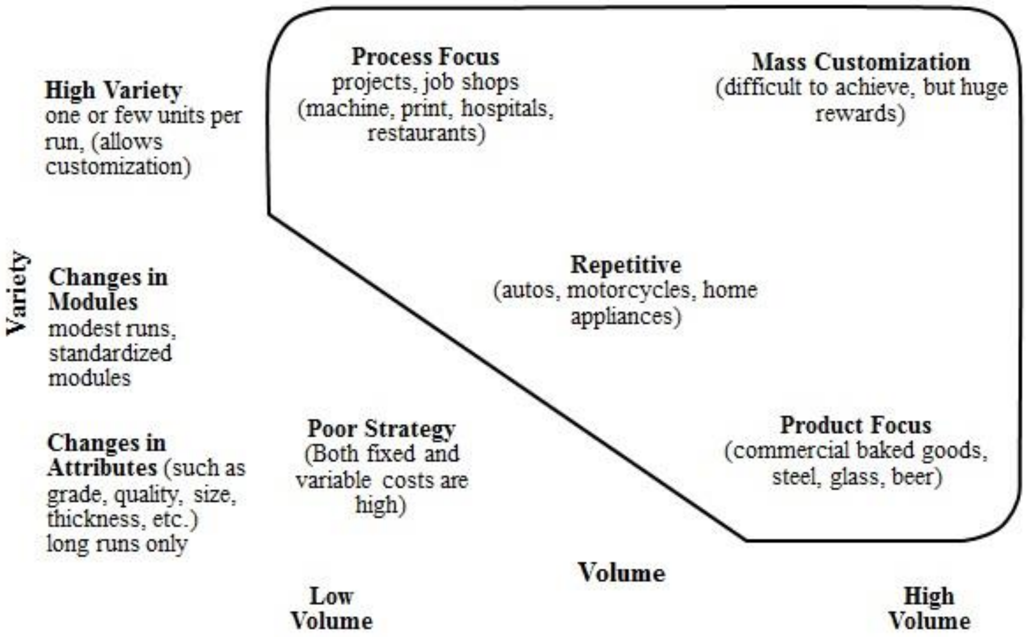


Figure 1: Four Types of Processes (Heier and Render, 2014)

1.3. LAYOUT TYPES

1.3.1. THE STRATEGIC IMPORTANCE OF LAYOUT DECISIONS

A facility layout decision is one of the major fields of operations management in terms of efficiency. Layout decision is concerned with strategic arguments, because it determines the organization’s competitiveness in terms of capacity, flexibility, cost, customer interaction, image, and quality of workplace environment. It can help the organization manage according to their individual strategy, e.g., low cost, differentiation, or response. Therefore, the main objective of the layout decision is to design an efficient and effective layout that will satisfy the organization’s competitive requirements (Heizer and Render, 2014).

1.3.2. LAYOUT TYPES

The facility layout problem (FLP) is the efficient arrangement of interrelated facilities (departments, machines) on a manufacturing floor in order to satisfy the objectives of the firm (Aiello et al., 2013). An efficient arrangement of facilities enables the efficient flow of materials, personnel, and information within and among the areas. Various layout approaches have been evolved in order to achieve these objectives (Heizer and Render, 2014). These layout approaches are identified in accordance with the production process, i.e., if the company has a process focus manufacturing plan, then the company should apply process-oriented layout in order to comply with the manufacturing plan.

The various layout approaches are office layout, retail layout, warehouse layout, fixed-position layout, work-cell layout, process-oriented layout, and product-oriented layout (Heizer and Render, 2014). Two of these, process-oriented layout, and product-oriented layout will be explained in details.

Process-oriented Layout: Process-oriented layout engages in low-volume, high-variety production. The machines with same functional features are handled in the same area. It can be called as functional layout, in which the machines should need flexibility to be able to produce the various products. High product variety is provided by the necessary adjustments on machines made by highly-skilled workers.

Since a high variety of products are processed, a high level of flexibility is demonstrated as the materials are transported between departments. Therefore, the facilities (departments, machines) that have intense flows of materials, personnel, and information between each other should be settled adjacent.

The main advantages of the process-oriented layout are as follows (Ureten, 2013):

- It enables the production of various products.
- The production tools are flexible.
- It minimizes the failure of production, due to breakdown, repair, and maintenance.
- It provides a job satisfaction among workers because of the variety of tasks.
- The personal motivation and rewards to the high-skilled workers are high.

- The location of similar machines adjacent enables flexibility.

The main disadvantages of the process-oriented layout are as follows (Ureten, 2013):

- The capacity utilization rate is low, in other words, the amount of idle time, or the number of idle workers is high.
- Material handling costs and volumes are high.
- Work-in-process inventory and the need for the area to store them are high.
- The labor cost is high because of the need for high-skilled workers.
- The production time is long, and the efficiency is low.
- The variable costs and the cost per product are high.

Product-oriented Layout: Product-oriented layout engages in high-volume, low-variety production. In a facility, each product has to follow the same production sequences in order to produce standardized products. The machines are arranged based on the order of processes. A high volume of production requires high levels of demand for standardized products.

The main advantages of the product-oriented layout are as follows (Ureten, 2013):

- Material handling volumes are high; the work-in-process inventory is low.
- The cost per product is low.
- The labor cost is low, because it does not require high-skilled workers.
- Since the work-in-process inventory is low, the need for storage space is also low.
- The capacity utilization rate is high.
- The production time is short, and the efficiency is high.

The main disadvantages of the product-oriented layout are as follows (Ureten, 2013):

- The flexibility is low; therefore it may be difficult to make adjustments.
- The costs caused by the failure of production, due to breakdown, repair, and maintenance are high.
- The fixed cost of special-purpose machinery is high.
- Continuity is necessary for the procurement of materials.
- Enlargement is almost impossible.
- The personal motivation and rewards to the workers are low due to monotony.

In light of this information, the layout decision should be made based on the necessities of the process.

1.4. LAYOUT MODELLING

In recent years, the most important manufacturing issue is the efficient use of scarce resources. Within this context, the design of the facility, which may be defined as the physical arrangement of a facility, is strongly associated with this perspective. The tangible fixed assets (building, machines, etc.) are organized in such a manner that the efficient use of resources is improved (Ashayeri et al., 2005).

The facility layout problem (FLP) is the organization of efficient arrangement of interrelated facilities (departments, machines) on a manufacturing floor in order to satisfy the objectives of the firm (Aiello et al., 2013). FLP deals with the optimality on placement of facilities (departments, machines) in order to minimize the operation costs and maximize the system utilization (Aiello et al., 2012). In other words, FLP is concerned with the location of facilities (departments, machines), i.e., which facilities (department, machines) are located adjacently (Wäscher and Merker, 1997).

An unfavorable layout, without regard to other factors, refers to inefficiency (Abdinnour-Helm and Hadley, 2000). Therefore, the most interacted facilities (departments, machines) are positioned next to each other so as to minimize material handling time, waiting time in queue, processing time, and to maximize throughput and machine utilization (Altuntas and Selim, 2012). The interactions between the facilities (departments, machines) denote the flow of items (material, personnel, information) between the departments.

An efficient arrangement of facility reduces the material handling cost, lead time, production time, and as a consequence, enhances the productivity (El-Baz, 2004), while an unfavorable layout leads to inefficient material handling with an extensive amount of work-in-process inventory (Chiang and Chiang, 1998).

Generally speaking, between 20% and 50% of operation cost is related with material handling. Since the minimization of material handling cost is the main objective of the facility layout planning, previous research has indicated that such minimization can result a cost reduction in between 10% and 30% (Tompkins et al., 1996).

The minimization of material handling cost is a commonly-used objective in mathematical models; however, there are also qualitative criteria, such as flexibility, safety, and aesthetics of the facility (Francis et al., 2009) to be taken into consideration (Singh and Sharma, 2006).

The simplest FLP is called static facility layout problem (SFLP), which deals with the arrangement of same-sized facilities with a constant flow between them. SFLP is formulated as a as a quadratic assignment problem (QAP) by Koopmans and Beckmann (1957) (Bozorgi et al., 2015).

Facility layout problems are demonstrated as NP-hard, in which the exact solution is nearly impossible within a reasonable computation time (Amaral, 2013). In NP-hard problems, exact solution methods are only applicable for small-sized problems (Francis et al., 2009); therefore, former research includes solution techniques based on heuristics and metaheuristics (Castillo and Sim, 2004).

1.5. PROBLEM STATEMENT

Although the facility layout problem was one of the main research topics in industrial engineering and operations management areas, very little research has focused on the evaluation of facilities' layout. Most research aims to develop mathematical, heuristics, metaheuristics, and simulation models to constitute a layout, but fails to examine the performance of it. However, the evaluation process of a layout is equally as important as the constitution of it.

The models for the evaluation of the layout, in fact, evaluate the performance of the operations. The evaluation of layout should examine the main characteristics of layouts before the operation started to avoid high costs and loss of time caused by the re-layout process. Therefore, for the performance evaluation of a layout, the indices, in other words, the criteria, should be specified in order to gain insight into the impacts depending on a layout alternative (Lin and Sharp, 1999).

The criteria or indexes which are identified in previous research are as follows:

Gantz and Pettit (1953) determined eleven indexes, namely, index of indirect materials handling, index of direct materials handling, index of gravity utilization, primary index of automatic machine loading, secondary index of automatic machine loading, index of production line flexibility, index of workstation flexibility, index of floor-area loading density, index of aisle space, index of storage space, and index of storage volume utilization.

Muther (1973) discussed twenty potential criteria, namely, ease of future expansion or contraction, adaptability and versatility, layout flexibility, flow or movement effectiveness, materials-handling effectiveness, storage effectiveness, space utilization, supporting service integration, safety and housekeeping, working conditions and employee satisfaction, ease of supervision and control, appearance, promotional value, public or community relations, quality of the product, maintenance, fitness with organization structure, equipment utilization, security and theft, utilization of natural conditions, ability to meet capacity, and compatibility with long-range plans.

Konz (1985) determined three ratio classifications, namely, resource utilization ratios (for people, equipment, space, and energy), management control ratios (for materials, movement, and loss), and operation efficiency ratios (for manufacturing, storage and retrieval, receiving and shipping) (Lin and Sharp, 1999).

Lin and Sharp (1999) developed 18 criteria, namely, initial cost, annual operation and maintenance cost, future salvage value, raw materials inventory holding cost, work-in-process (WIP) inventory holding cost, finished goods inventory holding cost, clearness, space sufficiency and utilization, aisle, distance and volume density, robustness of equipment capacity, building expansion, topography and topology, community environment, human-related safety, worker-related comfort, property-related security, and access for maintenance.

The limitations of the criteria or indexes determined in previous research are as follows:

1. The criteria or index set determined in previous research did not fully describe the effectiveness of the layout. For example, Lin and Sharp's (1999, 1999b) criteria set lacks flexibility criteria, time criteria, and also lacks many measurements.

2. The appropriate data are not available before the operations start. The machines are arranged into current locations, then the performance of the facility layout will be assessed after the operation started; however, it may lead to a need for rearrangement in cases where the effectiveness of the facility cannot be achieved (Lin and Sharp, 1999).

3. There is almost no validation accessed to assure the practicability of the criteria and the indexes. In other words, the applicability of the criteria and the indexes are not clear, because they are not justified.

4. Some of the criteria or the index parameters are sometimes not practical for the real-life cases. For example, the parameters of appearance, promotional value,

public or community relations, and fitness with organization structure criteria in Muther's (1973) approach are hard to obtain and estimate.

Therefore, in this dissertation, firstly, the main criteria were set, then the sub-criteria were determined, and finally the measurement variables were identified. This dissertation has three main contributions:

1. We have categorized the indices as Criteria, Sub-Criteria, and Measurement.

2. The criteria set are an extended set to fully describe the dimensions of the layout effectiveness.

3. We have integrated four different MCDM techniques in a hybrid model for the performance assessment.

Within this context, the criteria set were identified as seen in Table 1. There are 7 main criteria, 19 sub-criteria, and 114 measurements.

Table 1: The Criteria Set and the Measurements

MAIN CRITERIA	SUB-CRITERIA	MEASUREMENTS
Cost		
	Non-Inventory Cost	
		Land Cost
		Building Cost (Floor Construction Cost)
		Production Machinery Cost
		Material Handling Cost
		Labor Cost
		Maintenance Cost
		Future Salvage Value
		Quality Cost
		Capital Cost of Material Handling Equipment (Investment)
		Rearrangement Cost
		Setup Cost
		Energy Cost
		Safety Cost
		Manufacturing Operation Cost
	Inventory Cost	
		Raw Material Inventory Holding Cost
		WIP Inventory Holding Cost
		Finished Goods Inventory Holding Cost

		Backordering Cost
		Loss (Production+Damage+Spoilage+Obsolescence)
Flow		
	Space Relationship	
		Value-Added Area
		Non-Value Added Area
		Storage Space (m^3)
		Dead (Empty) Space (m^3)
		Required Area (Area Requirements)
		Space Efficiency (m^3)
		Space Utilization (m^3)
	Material Flow	
		Volume
		Dimensions of the Aisles
		Number of Loaded Travel of Material Handling Equipment
		Number of Empty Travel of Material Handling Equipment
		Adjacency Score
		Speed
		Intermodule Distances
		Accessibility
		Aspect Ratio
		Interferences (Overlapping)
	Non-Material Flow	
		Information Flow (Frequency)
		Personnel Flow (Frequency)
		Equipment Flow (Frequency)
Flexibility		
	Robustness	
		Robustness of Equipment
		Building Expansion
		Free Space Availability
	Volume Flexibility	
		Adaptation to Variations in Production Volume
		Adaptation to Variations in Demand Volume
		Adaptation to Variations in Material Handling Cost
		Adaptation to Variations in Material Flow
		Adaptation to Variations in Equipment
		Adaptation to Variations in Technology
		Adaptation to Variations in Product Mix
		Adaptation to Variations in Order Arrival Time

		Adaptation to Variations in Processing Requirements
		Adaptation to Variations in Due Date Requirements
		Adaptation to Variations in Processing Time
	Routing Flexibility	
		Average Number of Alternate Routes
		Accessibility of Alternate Routes
Surrounding Environment		
	Topography and Topology	
		Natural Site Conditions and Construction
		Truck Access and Circulation Pattern
		Connection with External Material Handling Equipment
	Community Environment	
		Impact of Traffic Congestion and Noise
		Waste Management and Pollution Control
		Appearance of External or Viewable Features
Environment Quality		
	Human-related Safety	
		Human Building Accidents
		Human Vehicle Crossings
		Human/Machine/Material/ Material Handling Interfaces
		Fire / Earthquake / Evacuation
	Worker-related Comfort	
		Lighting
		Aesthetics
		Ease of Supervision
		Noise
		Ventilation/Heating
		Ergonomics
		Handicapped Access
		Employee Satisfaction
		Hygiene
		Humidity
		Pressure
		Signs & Artifacts
	Property-related Security	
		Theft from outside the Building
		Theft from within the Building
		Special Caution for Dangerous Areas

	Maintenance	
		Compatibility of Building Construction and Material Handling Equipment
		Space for Maintenance Work
		Appropriate Location of Maintenance Activities
		Complexity of Material Handling Equipment
	Sustainability	
		Number of Reused/Recycled Materials
		Environmental Sustainability Index
		Environmental Performance Index
Time		
	Time in Production	
		Production Time
		Setup Time
		Throughput Time
		Overall Processing Time
		Cycle Time
		Idle Time
	Time in non-Production	
		Storage Time
		Retrieval Time
		Loading Time
		Unloading Time
		Stoppages
		Transportation Time (Flow Time)
Characteristics		
	Production Characteristics	
		Production Volume
		Production/Machine Capacity
		Total Quality Management (Kaizen)
		Quality of Product
		Raw Material Inventory
		WIP Inventory
		Finished Goods Inventory
	Other Characteristics	
		Average Machine Utilization
		Size (Department, Block, Cell)
		Shape of Departments
		Shape of Machines
		Number of Departments
		Number of Machines
		Average Availability of Facilities

		Manpower Requirements (Skills, Qualifications)

CHAPTER 2: LITERATURE REVIEW

This section will include two sub-sections. The first section will include the literature about layout modelling, and the second one about the performance assessment of layout.

2.1. LAYOUT MODELLING

The facility layout analysis is a much-studied combinatorial optimization problem which takes place in many applications (Singh and Sharma, 2006).

Two popular approaches were considered for facility layout problem (FLP) design. The first deals with the environment of FLP, which is whether it is certain or uncertain. The problem data, for instance, demand, is deterministic in certain environments, and stochastic in uncertain environments. The second approach deals with the flexibility of FLP, i.e. whether it is static or dynamic. Both approaches are planned in single or multi-period time horizons (Moslemipour et al., 2012).

Up to the present, many different solution techniques have been applied. There is no exact best solution approach for the FLP; the solution technique is selected in accordance with the characteristics of the problem.

Generally, the solution techniques may be classified in four categories: exact methods, heuristics, metaheuristics, and hybrid approaches (Moslemipour et al., 2012).

2.1.1. EXACT METHODS

Exact methods, in other words, optimal algorithms, are only available for small-sized facility layout problems, and aim to find an optimal solution. They consist of branch and bound algorithms, cutting plane algorithms and the dynamic programming.

2.1.2. HEURISTICS

Heuristic algorithms, which are also called as sub-optimal algorithms or computerized layout algorithms (Francis et al., 2009), are used to solve the facility layout problems with unequal or equal-sized facilities in a reasonable computation time. Such algorithms can reveal high-quality solutions (Kusiak and Heragu, 1987).

Generally, heuristic algorithms can be classified as construction and improvement (local search) algorithms.

2.1.3. METAHEURISTICS

A metaheuristic is a set of procedures organized to indicate and select the heuristic methods which are practicable for the various problems. These provide good-quality solutions in facility layout problems consisting of non-continuous, stochastic, and non-linear data (Dorigo and Stützle, 2004).

Generally, the metaheuristic algorithms consist of genetic algorithm (GA), tabu search (TS), simulated annealing (SA), ant colony optimization (ACO), artificial immune system (AIS), greedy randomized adaptive search procedure (GRASP), particle swarm optimization (PSO), expert systems (ES), fuzzy systems (FS) and artificial neural networks (ANN) algorithms (Moslemipour et al., 2012).

2.1.4. HYBRID APPROACHES

Hybrid approaches, designed to integrate different solution approaches, are used to solve the facility layout problems. For example, the solution approach organized as the integration of two metaheuristics, i.e., genetic algorithm and simulated annealing, can be considered as a hybrid approach.

Table 2 shows the complete list of relevant methodologies about FLP.

Table 2: The relevant methodologies about FLP

METHODOLOGIES	REFERENCE	Type
Tabu Search	Abdinnour-Helm and Hadley, 2000; Alvarenga et al., 2000; Bozorgi et al., 2015; Chiang and Chiang, 1998; Chiang, 2001; Chittratanawat and Noble, 1999; Dokeroglu, 2015; Kulturel-Konak et al., 2004; Kulturel-Konak, 2012; Kothari and Ghosh, 2013b; Liang and Chao, 2008; Logendran and Kriausakul, 2006; McKendall Jr and Liu, 2012; McKendall Jr and Hakobyan, 2010; Ou-Yang and Utamima, 2013; Palubeckis, 2012; Samarghandi and Eshghi, 2010; Samarghandi and ElMekkawy, 2012; Samarghandi et al., 2013; Scholz et al., 2009; Ye and Zhou, 2007; Zuo et al., 2014	Heuristics
Mixed Integer LP	Abedzadeh et al., 2013; Acar et al., 2009; Amaral, 2006; Amaral, 2009; Amaral, 2012, Amaral, 2013; Amaral, 2013b; Bozer and Wang, 2012; Castillo and Westerlund, 2005; Castilo and Peters, 2004; Chae and Peters, 2006b; Chiang et al., 2006; Chung and Tanchoco, 2010b; Delmaire et al., 1997; Dunker et al., 2003; Foroughi, 2011; Gamberi et al., 2009; Georgiadis et al., 1999; Hathhorn et al., 2013; Hwang, 2004; Ioannou, 2006; Ioannou, 2007; Khaksar-Haghani et al., 2013; Kia et al., 2014; Kim and Goetschalckx, 2005; Kim and Kim, 2000; Kim and Kim, 2003; Kulturel-Konak and Konak, 2013; Kulturel-Konak and Konak, 2015; Konak et al., 2006; Kulturel-Konak, 2012; Kosucuoglu and Bilge, 2012; Lacksonen, 1997; Li and Rong, 2009; Liu and Meller, 2007; McKendall Jr et al., 1999; Meller et al., 2007; Meller et al., 2010; Meller, 1997; Murray, et al., 2013; Ozyurt and Realff, 1999; Salmani et al., 2015; Tavakkoli-Moghaddam et al., 2007; Toloo, 2012; Toloo, 2014; Toloo, 2015; Urban et al., 2000; Zhang and Murray, 2012; Zuo et al., 2014	Optimization
Simulation	Acar et al., 2009; Altuntas and Selim, 2012; Azadeh et al., 2011; Azadeh et al., 2013; Azadeh et al., 2014; Azadeh et al., 2015; Azadivar and Wang, 2000; Chung and Tanchoco, 2010; Dombrowski and Ernst, 2013; Gamberi et al., 2009; Hsieh et al., 2012; Kim et al., 2014; Kulturel-Konak et al., 2004; Luo et al., 2015; Pandey et al., 2000; Suhadak et al., 2015; Sukhotu and Peters, 2012; Wang and Chen, 2008; Zhang et al., 2011; Zhao and Tseng, 2007	Heuristics
Genetic Algorithm	Adrian et al., 2015; Ahmad et al., 2006; Aiello et al., 2002; Aiello et al., 2012; Aiello et al., 2013; Alagoz et al., 2008; Al-Hakim, 2000; Azadivar and Wang, 2000; Balakrishnan et al., 2003; Caputo et al., 2015; Datta et al., 2011; Deb and Bhattacharyya, 2005; Delmaire et al., 1997; Diego-Mas et al., 2009; Dunker et al., 2005; Eklund et al., 2006; El-Baz, 2004; Emami and Nookabadi, 2013; Enea et al., 2005; Filho and Tiberti, 2006; Garcia-Hernandez et al., 2013; Garcia-Hernandez et al., 2013b; Garcia-Hernandez et al., 2015; Garcia-Hernandez et al., 2015b; Gau and Meller, 1999; Gonçalves and Resende, 2015; Gress et al., 2011; Hamamoto, 1999; Haq et al., 2003; Hauser and Chung, 2006; Hicks, 2006; Hu et al., 2007; Hwang, 2004; Islier, 1998; Izui et al., 2013; Jabal-Ameli and Moshref-Javadi, 2014; Jiang et al., 2014; Kalita and Datta, 2014; Kaveh et al., 2014; Keshavarzmanesh et al., 2010; Khaksar-Haghani et al., 2013; Kia et al., 2014; Kochhar et al., 1998; Kochhar and Heragu, 1999; Kulturel-Konak and Konak, 2013; Kosucuoglu and Bilge, 2012; Kothari and Ghosh, 2014b; Krishnan et al., 2012; Ku et al., 2011; Kundu and Dan, 2010;	Heuristics

	Lee and Lee, 2002; Lee et al., 2003; Lee et al., 2005; Lenin et al., 2013; Leno et al., 2013; Li and Love, 2000; Liu and Meller, 2007; Liu and Sun, 2012; Mak et al., 1998; Matsuzaki et al., 1999; Mavridou and Pardalos, 1997; Mazinani et al., 2013; Hosseini-Nasab, 2014; Parwananta et al., 2013; Pourvaziri and Naderi, 2014; Rajasekharan et al., 1998; Ripon et al., 2013; Sadrzadeh, 2012; Shayan and Chittilappilly., 2004; Sirinaovakul and Limudomsuk, 2007; Tam and Chan, 1998; Tosun et al., 2013; Tunnukij and Hicks, 2009; Tuzkaya et al., 2013; Wu and Appleton, 2002b; Yalaoui et al., 2011; Yang et al., 2011; Ye and Zhou, 2007; Zhang et al., 2000; Jiang and Nee, 2013	
Particle Swarm Optimization	Adrian et al., 2015; Hosseini-Nasab and Emami, 2013; Jolai et al., 2012; Kheirkhah, et al., 2015; Kulturel-Konak and Konak, 2011; Lien and Cheng, 2012; Luo et al., 2015; Ou-Yang and Utamima, 2013; Paul et al., 2006; Samarghandi et al., 2010; Samarghandi and ElMekkawy, 2012	Heuristics
Ant Colony Optimization	Adrian et al., 2015; Baykasoglu et al., 2006; Chen, 2013; Guan and Lin, 2016; Komarudin and Wong, 2010; Kulturel-Konak and Konak, 2011b; Li and Rong, 2009; McKendall Jr and Shang, 2006; Nourelfath et al., 2007; Ramkumar et al., 2009; Solimanpur et al., 2004; Solimanpur et al., 2005; Wong and Komarudin, 2010; Yalaoui et al., 2011	Heuristics
Fuzzy α Cuts	Aiello and Enea, 2001	Heuristics
Simulated Annealing	Al-Araidah et al., 2007; Alvarenga et al., 2000; Ariafar and Ismail, 2009; Balakrishnan et al., 2003; Barral et al., 2001; Bazargan-lari and Kaebernick, 1997; Bozer and Wang, 2012; Castillo and Peters, 2002; Chae and Peters, 2006; Chiang and Chiang, 1998; Chwif et al., 1998; Deb and Bhattacharyya, 2005; Dong et al., 2009; Emami and Nookabadi, 2013; Haq et al., 2003; Hosseini et al., 2014; Hosseini-Nasab and Emami, 2013; Ioannou, 2007; Kaveh et al., 2014; Kim and Goetschalckx, 2005; Kim and Kim, 1998; Kim and Kim, 2003; Kulturel-Konak and Konak, 2015; Ku et al., 2011; Li et al., 2015; Matai et al., 2013b; Matai, 2015; Matsuzaki et al., 1999; Mavridou and Pardalos, 1997; McKendall Jr et al., 2006; Moslemipour and Lee, 2012; Navidi et al., 2012; Palubeckis, 2015; Pillai et al., 2011; Pourvaziri and Naderi, 2014; Sahin and Turkbey, 2009; Sahin and Turkbey, 2009b; Sahin et al., 2010; Sahin, 2011; Saraswat et al., 2015; Singh and Sharma, 2008; Tubaileh, 2014; Tuzkaya et al., 2013; Wang et al., 1998; Wang et al., 2001; Wang et al., 2015; Wu and Appleton, 2002; Xiao et al., 2013	Heuristics
Mathematical Programming	Allahyari and Azab, 2015; Benjaafar and Sheikhzadeh, 2000; Bock and Hoberg, 2007; Drezner, 2010; Huang et al., 2003; Jankovits et al., 2011; Raminfar et al., 2013; Tari and Neghabi, 2015; Wang et al., 2015	Optimization
Weighted Association Rule-Based Data Mining	Altuntas and Selim, 2012	Optimization
Fuzzy DEMATEL	Altuntas et al., 2014	Heuristics
P-median Clustering	Ashayeri et al., 2005	Heuristics
Data Envelopment Analysis	Azadeh et al., 2011; Azadeh et al., 2013; Azadeh et al., 2014; Azadeh et al., 2015; Bozorgi et al., 2015; Ertay et al., 2006; Foroughi, 2011; Kuo et al., 2008; Toloo and Nalchigar, 2009; Toloo, 2012; Toloo, 2014; Toloo, 2015; Yang and Kuo, 2003	Optimization
Non-linear Goal Programming	Bazargan-lari and Kaebernick, 1997; Castillo and Sim, 2004	Optimization
Graph Theoretic Model	Caccetta and Kusumah, 2001; Kim and Kim, 1995; Kim et al., 1995; Foulds	Heuristics

	and Partovi, 1998	
Mixed Integer Non-Linear	Castillo and Peters, 2002; Castillo and Peters, 2003; Chiang et al., 2006; Chittratanawat and Noble, 1999; Hadi-Vencheh and Mohamadghasemi, 2013; Irani and Huang, 2000; Javadi et al., 2013; Jia and Seo, 2013; Jolai et al., 2012; Kosucuoglu and Bilge, 2012; Lira-Flores et al., 2014; Logendran and Kriausakul, 2006; Mohamadghasemi and Hadi-Vencheh, 2012; Rastpour and Esfahani, 2010; Solimanpur and Jafari, 2008; Taghavi and Murat, 2011; Vázquez-Román et al., 2010; Vázquez-Román et al., 2015; Wang and Chen, 2008; Xiao et al., 2013	Optimization
Slicing Tree Structure (Genetic Algorithm)	Chang and Ku, 2013; Diego-Mas et al., 2008; Diego-Mas et al., 2009; Liu and Sun, 2012; Río-Cidoncha et al., 2007; Scholz et al., 2009	Heuristics
Fuzzy Weighted Average	Chang et al., 2009	Heuristics
Multi-pass halving and doubling procedure	Chen and Sha, 2005	Heuristics
Particle Bee Algorithm	Cheng and Lien, 2012; Lien and Cheng, 2012; Saravanan and Arulkumar, 2015	Heuristics
Fuzzy Inference System	Deb and Bhattacharyya, 2003; Deb and Bhattacharyya, 2005b	Heuristics
Best Insertion Heuristics	Djellab and Gourgand, 2001	Heuristics
Teaching-Learning-Based Optimization	Dokeroglu, 2015	Heuristics
Fuzzy Evolutionary Algorithm	Drira et al., 2013	Heuristics
Fuzzy TOPSIS	Emami and Nookabadi, 2013	Heuristics
Analytic Hierarchy Process	Ertay et al., 2006; Hadi-Vencheh and Mohamadghasemi, 2013; Jiang et al., 2014; Singh and Singh, 2011; Foulds and Partovi, 1998; Jiang and Nee, 2013; Yang and Kuo, 2003	Heuristics
Dispatching Algorithm	Gamberi et al., 2009	Heuristics
Self-Organizing Map	U-Yeol and Sung-Hoon, 2012	
Entropy	Gonzalez-Cruz and Martinez, 2011	Heuristics
Analytic Network Process	Al-Hawari et al., 2014	Heuristics
Dynamic Programming	Urban, 1998	
Discrete Optimization	Hungerländer and Anjos, 2015	Optimization
Artificial Bee Colony Algorithm	Jia and Seo, 2013	Heuristics
Psychoclonal Algorithm	Khilwani et al., 2008	Heuristics
Insertion-based Lin–Kernighan Heuristic	Kothari and Ghosh, 2013	Heuristics
Scatter Search Algorithm	Kothari and Ghosh, 2014	Heuristics
Grey Relation Analysis	Kuo et al., 2008	Heuristics
Preference Selection Index	Maniya and Bhatt, 2011	Heuristics
Triangulation Expansion Heuristics	Merker and Wascher, 1997	Heuristics
Migrating Birds Optimization	Niroomand et al., 2015	Heuristics
MCDM Integration	Shokri et al., 2013; Yang et al., 2013; Hadi-Vencheh and Mohamadghasemi, 2015	Heuristics

Queuing Theory	Smith, 2010; Sukhotu and Peters, 2012	Heuristics
Neural Networks	Tsuchiya et al., 1996	Heuristics
TOPSIS	Yang and Hung, 2007	Heuristics
Clonal Selection Algorithm	Ulutas and Islier, 2009; Ulutas and Islier, 2015; Ulutas and Kulturel-Konak, 2012; Ulutas and Kulturel-Konak, 2013	Heuristics
Fuzzy Heuristic	Evans et al., 1987; Raoot and Rakshit, 1991	Heuristics
Fuzzy AHP	Dweiri, 1999	Heuristics

2.2. PERFORMANCE ASSESSMENT

Apart from the literature about layout modelling, to the best of our knowledge, very little research investigates for the performance assessment of facilities' layout.

Gantz and Pettit (1953) determined eleven indexes, namely, index of indirect materials handling, index of direct materials handling, index of gravity utilization, primary index of automatic machine loading, secondary index of automatic machine loading, index of production line flexibility, index of workstation flexibility, index of floor-area loading density, index of aisle space, index of storage space, and index of storage volume utilization.

Muther (1973) discussed twenty potential criteria, namely, ease of future expansion or contraction, adaptability and versatility, layout flexibility, flow or movement effectiveness, materials-handling effectiveness, storage effectiveness, space utilization, supporting service integration, safety and housekeeping, working conditions and employee satisfaction, ease of supervision and control, appearance, promotional value, public or community relations, quality of the product, maintenance, fitness with organization structure, equipment utilization, security and theft, utilization of natural conditions, ability to meet capacity, and compatibility with long-range plans.

Konz (1985) determined three ratio classifications, namely, resource utilization ratios (for people, equipment, space, and energy), management control ratios (for materials, movement, and loss), and operation efficiency ratios (for manufacturing, storage and retrieval, receiving and shipping) (Lin and Sharp, 1999).

Lin and Sharp (1999) developed 18 criteria, namely, initial cost, annual operation and maintenance cost, future salvage value, raw materials inventory holding cost, work-in-process (WIP) inventory holding cost, finished goods inventory holding cost, clearness, space sufficiency and utilization, aisle, distance and volume density, robustness of equipment capacity, building expansion, topography and topology, community environment, human-related safety, worker-related comfort, property-related security, and access for maintenance.

CHAPTER 3: METHODOLOGY

The model, which is called hybrid multi criteria decision-making (MCDM) model, consists of different MCDM techniques. Firstly, fuzzy Total Interpretive Structural Modelling (TISM) technique is applied in order to determine the relationships between a set of criteria. Then, fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) technique is employed to identify the causal relationships. In the next step, with the help of the output of the fuzzy DEMATEL method, inner-dependence matrix, fuzzy Analytical Network Process technique is applied in order to determine the weights of sub-criteria. After determining the weights of the sub-criteria, the weights of corresponding measurements are found using fuzzy Analytical Hierarchy Process technique. Thus, the structural causal relationship, the weights of sub-criteria, and the weights of the measurements are found. Finally, all found indices are multiplied by the performance indices in order to calculate the overall performance assessment score.

3.1. FUZZY SET THEORY

The decision-makers experience uncertainties in the decision-making process due to the subjective manner of their judgments. To deal with this subjectivity and vagueness in human judgment, Zadeh (1965) introduced the fuzzy set theory to demonstrate the linguistic terms used when dealing with a decision process. In the theory, mathematical operators and programming are also allowed to apply to the fuzzy domain. A class of objects with a continuum of grades of membership is called a fuzzy set. Characteristic function is used to assign a grade of membership (from zero to 1) to each object and this grade characterizes fuzzy sets. If a fuzzy set is represented by a symbol, then a tilde "~" is placed above the symbol (Zadeh, 1965).

There are various fuzzy membership functions. In this paper, we use triangular fuzzy numbers. A triangular fuzzy number (TFN), $\tilde{M}$, is shown in Figure 2.

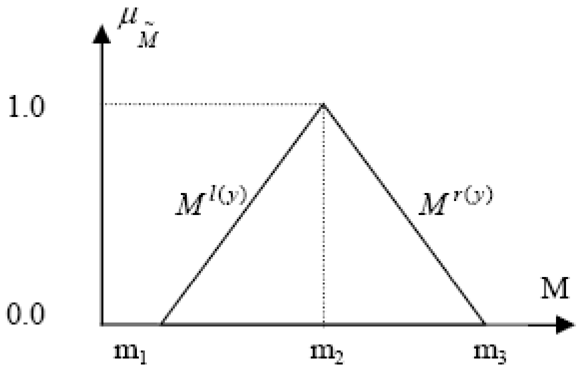


Figure 2: A Triangular Fuzzy Number

A triangular fuzzy number is indicated as (l_{ij}, m_{ij}, r_{ij}). The parameters l_{ij}, m_{ij}, r_{ij} respectively refer the smallest possible, the most promising, and the largest possible values that characterize a fuzzy event.

3.2. FUZZY TOTAL INTERPRETIVE STRUCTURAL MODELING (TISM)

3.2.1. TOTAL INTERPRETIVE STRUCTURAL MODELING (TISM)

Interpretive Structural Modelling (ISM) is one the well-known multi criteria decision-making (MCDM) methods (Khatwani et al., 2015). It is a methodology that aims to explain the relationships between a set of criteria related to the decision problem (Jharkharia and Shankar, 2005).

As in all MCDM methods, the process starts with determining the relevant criteria about the decision problem, immediately after which, a structural self-interaction matrix (SSIM) is constructed with the help of pairwise comparison matrices. Then, SSIM is transformed into reachability matrix by checking the transitivity options. Finally, the criteria are divided into partitions in order to extract the final structural model, called as ISM (Agarwal et al., 2007). Within this context, like other MCDM methods, the crisp values lack of adequacy to model the uncertain scenarios. To deal with this subjectivity and vagueness of human judgment, fuzzy set theory is integrated to the decision-making process (Fan and Liu, 2010; Xu, 2004; Xu, 2006; Xu and Da, 2008; Wei, 2009).

The reachability matrix is constituted by converting the relationship symbols of SSIM into 0 and 1. Since the true maximum and minimum values cannot reflect the extreme values of 0 and 1, the extreme values are not able to express the relationship of criteria. Previous research has attempted to upgrade ISM to Total Interpretive Structural Modelling (TISM) in order to elucidate the model fully interpretively (Sushil, 2012).

TISM is proposed by Sushil (2012), and derived from ISM methodology originated from Warfield (1973, 1974). ISM enables the graphical presentation of complicated systems (Sushil, 2012). TISM enables researchers to constitute complex relationships between various criteria (Farris and Sage, 1975), and also allows both the direct and transitive relationships between the criteria to develop the structural model fully explanatory (Khatwani et al., 2015).

The main steps of TISM are as follows:

Developing SSIM: The relationship between two criteria is identified by expert opinion with the help of pairwise comparison matrices. Four symbols, that is to say, X, A, V, and O, are used to indicate the relationship between two criteria (Khatwani et al., 2015).

Developing Reachability Matrix: The reachability matrix is constituted by converting the relationship symbols of SSIM into 0 and 1.

Transitivity Check on Reachability Matrix: The transitivity check should be made on developed reachability matrix until the full transitivity is constituted according to the transitivity rule.

Reachability Matrix Partition: The criteria are divided into partitions in order to create digraph and present the final model. The partition process is facilitated by level partition and relation partition on criteria and its sub-criteria (Warfield, 1974).

Creating Digraph for TISM: The relationships between the criteria are constituted using directed arrows. The constituted digraph is complicated, and should be analyzed to remove transitivity, after which the digraph for TISM is finalized (Khatwani et al., 2015).

Final TISM Model: Final TISM model is constructed by indicating direct and transitive links to justify the influence level of a criterion to another.

3.2.2. FUZZY-TISM: A FUZZY EXTENSION of TISM

The linguistic variables for the pairwise comparisons are shown in Table 3. Triangular fuzzy numbers, shown in Figure 3, are used to convert the linguistic variables into numerals. The symbols used to describe the fuzzy interrelationships are shown in Figure 4.

Table 3: Fuzzy Linguistic Scale

Linguistic terms	Triangular fuzzy numbers
Very high influence (VH)	(0.75,1.0,1.0)
High influence (H)	(0.5,0.75,1.0)
Low influence (L)	(0.25,0.5,0.75)
Very low influence (VL)	(0,0.25,0.5)
No influence (No)	(0,0,0.25)

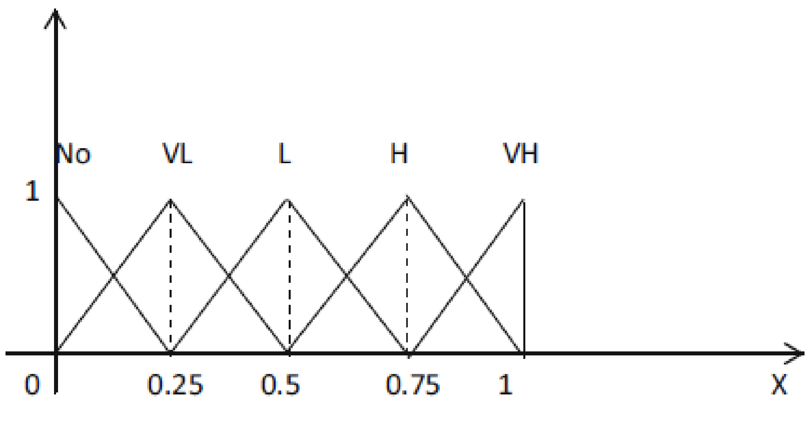


Figure 3: Triangular Fuzzy Numbers

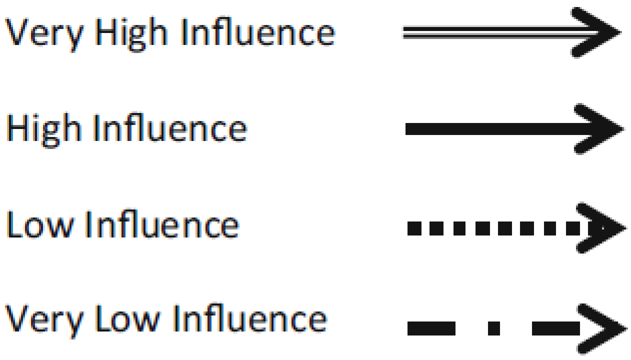


Figure 4: Symbols for Representation of Fuzzy Relationship Between Criteria

The main steps of fuzzy TISM are as follows (Khatwani et al., 2015):

Step 1: *Start of Decision Making Process*: Decision-making process consists of the following steps: (1) describing the decision goals, (2) collecting the relevant data, (3) identifying the possible alternatives, (4) assessing the alternatives with regard to their advantages and disadvantages, (5) selecting the best alternative, and (6) checking the results whether the decision goals have been attained or not (Hess and Siciliano, 1996; Opricovic and Tzeng, 2004). For this reason, the decision-making process starts with determining and describing the decision goals. Another important aspect is to appoint a committee for collecting the group knowledge for problem solving (Wu and Lee, 2007).

Step 2: *Selection of Criteria*: Due to the nature of influence/impact relationships between the criteria, they involve many complex aspects. The TISM method should be used to create a structural model in order to determine the influence level of one criterion on another. To deal with the subjectivity and vagueness of human judgment, the influence of the criteria between each other are expressed in five linguistic terms (Li, 1999) as No Influence (No), Very Low Influence (VL), Low Influence (L), High Influence (H), and Very High Influence (VH). Those linguistic terms are described in positive triangular fuzzy numbers (l_{ij}, m_{ij}, r_{ij}) as shown in Table 3.

Step 3: Gathering Responses and Creating SSIM Matrix: In order to fill in the SSIM matrix, a group of experts are asked to evaluate the influences of criteria on each other in order to measure the relationships between all criteria, that is, C = {C1, C2, …, Cn}. Four symbols, that is to say, X, A, V, and O, are used to indicate the relationship between the criteria (Khatwani et al., 2015). The meanings of those symbols are as follows:

i. Symbol V is used to indicate the influence/impact from the criterion i to the criterion j, but not vice versa. The influence/impact can be shown as V pursued by the linguistic terms, i.e., V (VH).

ii. Symbol A is used to indicate the influence/impact from the criterion j to the criterion i, but not vice versa. The influence/impact can be shown as A pursued by the linguistic terms, i.e., A (VH).

iii. Symbol X is used to indicate the influence/impact from both the criterion i to criterion j, and the criterion j to the criterion i. The influence/impact can be shown as X pursued by the linguistic terms, i.e., X (VH).

iv. Symbol O is used to indicate no influence/impact. The influence/impact can be shown as O pursued by the linguistic terms, i.e., A (No).

Step 4: *Calculation of Aggregated SSIM and Final Fuzzy Reachability Matrix*: Mode, which picks up the judgments of the respondents with the highest frequencies, has been used in order to get the aggregation of the judgments of the respondents to constitute the aggregated SSIM matrix. Then, aggregated SSIM matrix is converted into a fuzzy reachability matrix by replacing the linguistic terms with respective triangular fuzzy numbers. The following table, Table 4, shows the circumstances that take place during the conversion of aggregated SSIM matrix into final fuzzy reachability matrix (Khatwani et al., 2015).

Table 4: Fuzzy Numbers Used in Conversion Process

Mode Value of i-j	Fuzzy Number of i-j	Fuzzy Number of j-i
V(VH)	(0.75,1.0,1.0)	(0,0,0.25)
V(H)	(0.5,0.75,1.0)	(0,0,0.25)
V(L)	(0.25,0.5,0.75)	(0,0,0.25)
V(VL)	(0,0.25,0.5)	(0,0,0.25)
A(VH)	(0,0,0.25)	(0.75,1.0,1.0)
A(H)	(0,0,0.25)	(0.5,0.75,1.0)
A(L)	(0,0,0.25)	(0.25,0.5,0.75)
A(VL)	(0,0,0.25)	(0,0.25,0.5)
X(VH)	(0.75,1.0,1.0)	(0.75,1.0,1.0)
X(H)	(0.5,0.75,1.0)	(0.5,0.75,1.0)
X(L)	(0.25,0.5,0.75)	(0.25,0.5,0.75)
X(VL)	(0,0.25,0.5)	(0,0.25,0.5)
X(VH, H)	(0.75,1.0,1.0)	(0.5,0.75,1.0)
X(VH, L)	(0.75,1.0,1.0)	(0.25,0.5,0.75)
X(VH, VL)	(0.75,1.0,1.0)	(0,0.25,0.5)
X(H, VH)	(0.5,0.75,1.0)	(0.75,1.0,1.0)
X(H, L)	(0.5,0.75,1.0)	(0.25,0.5,0.75)
X(H, VL)	(0.5,0.75,1.0)	(0,0.25,0.5)
X(L, VH)	(0.25,0.5,0.75)	(0.75,1.0,1.0)
X(L, H)	(0.25,0.5,0.75)	(0.5,0.75,1.0)
X(L, VL)	(0.25,0.5,0.75)	(0,0.25,0.5)
X(VL, VH)	(0,0.25,0.5)	(0.75,1.0,1.0)
X(VL, H)	(0,0.25,0.5)	(0.5,0.75,1.0)
X(VL, L)	(0,0.25,0.5)	(0.25,0.5,0.75)
O(NO)	(0,0,0.25)	(0,0,0.25)

The final fuzzy reachability is stated as $\tilde{Z}$

$$\tilde{Z} = \begin{bmatrix} \tilde{Z}_{11} & \tilde{Z}_{12} & \cdots & \tilde{Z}_{1n} \\ \tilde{Z}_{21} & \tilde{Z}_{22} & \cdots & \tilde{Z}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{Z}_{n1} & \tilde{Z}_{n2} & \cdots & \tilde{Z}_{nn} \end{bmatrix}$$

where $\tilde{Z}_{ij} = (l_{ij}, m_{ij}, r_{ij})$.

Step 5: *Calculation of Driving Power and Dependence for MICMAC Analysis*: The driving power is computed by summing up the rows, and the dependence is computed by summing up the columns of the fuzzy reachability matrix. Then, defuzzification process is applied for the MICMAC analysis.

Step 6: *Reachability Matrix Level Partition*: The reachability matrix is partitioned with the help of relation partition and level partition. The transitivity should be checked before beginning the level partitioning.

Step 7: *Creating Fuzzy-TISM Digraphs and Defuzzified TISM Digraphs*: The symbols shown in Figure 4 are used to indicate the fuzzy relationship between criteria. Simple directed arrows are used to symbolize the degree of influence. H, and VH terms are transformed into 1, and VL, L, and No terms are transformed into 0 during the conversion of relationship symbols into 1 and 0.

The graph of fuzzy TISM model will occur as can be seen in Figure 5. Autonomous group (I) is situated in the south-west frame and has few links with the system. This group appears quite out of line with the system, denoting weak driving power and weak dependence. Dependent Group (II) is located in the south-east frame of the chart, are at the same time little influent and very dependent. The group denotes weak driving power and strong dependence. Linkage group (III) is situated in the north-east frame of the chart and is at the same time very influent and very dependent. The group denotes strong driving power and strong dependence. Independent Group (IV) is located in the north-west frame of the perception chart, and is very influent and little dependent. The group denotes strong driving power and weak dependence.

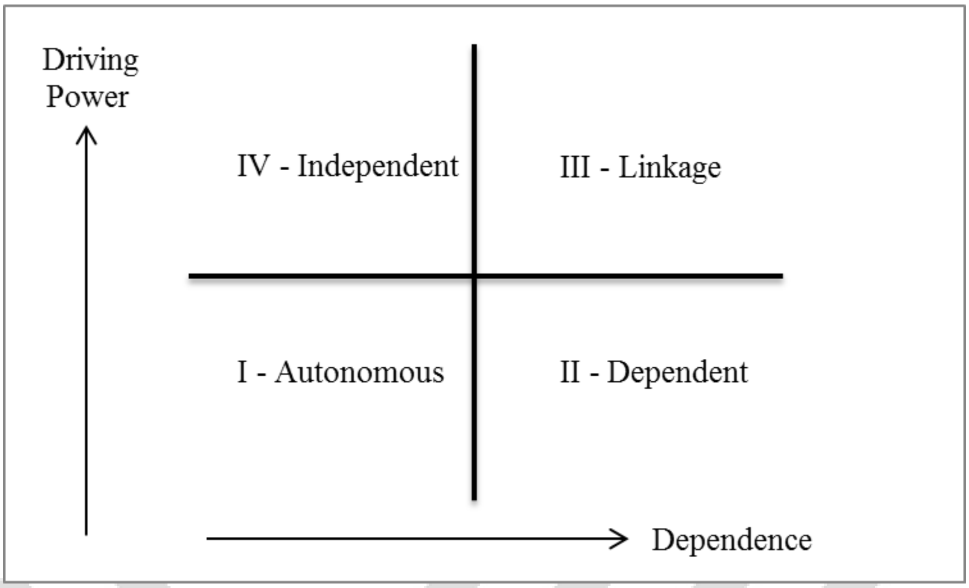


Figure 5: The Graph of Fuzzy TISM Model

3.3. FUZZY DEMATEL

Decision Making Trial and Evaluation Laboratory (DEMATEL) method measures the cause-effect relationships between complicated criteria in order to construct and analyze a structural model. The procedure of Fuzzy DEMATEL method will be discussed in the following sections.

3.3.1. DEMATEL METHOD

The DEMATEL method originated from The Battelle Memorial Institute, aiming to search for integrated solutions (Gabus and Fontela, 1972; 1973). The method became popular because it easily envisions the complex structure of cause-effect relationships (Lin and Wu, 2008).

The structure of DEMATEL method is subject to matrices or digraphs, which are able to distinguish the complicated criteria into cause and effect groups, and manage the inner dependencies. Digraphs are able to indicate the directed relationships of sub-systems; therefore, they are more practical and valuable than directionless graphs. A digraph may reflect a network, or a dominated relationship between criteria (Wu and Lee, 2007).

The matrices or digraphs represent the relations between the criteria, in which the numerical expressions show the strength of the influence. According to the fundamental principles of the DEMATEL method, the system consists of a set of criteria, that is, C = {C_1, C_2, …, C_n}, and the pairwise comparisons are used to show the mathematical relations (Tseng, 2009). Hence, the DEMATEL method intelligently shows the cause-effect relationships between the complicated criteria.

The solution steps are as follows:

Definition 1: The measurement scale for pairwise comparisons were designed as four levels, 0 (no influence), 1 (low influence), 2 (high influence), and 3 (very high influence).

Definition 2: The direct relation matrix, Z, is an *nxn* matrix acquired from pairwise comparisons based on relationships and influences between a set of criteria. Z_{ij} symbolizes the degree of the effect of criterion *i* to criterion *j*, i.e. Z = $[z_{ij}]_{nxn}$.

Definition 3: The normalized direct relation matrix, X, i.e., X = $[x_{ij}]_{nxn}$, and $0 \leq x_{ij} \leq 1$, is attained by way of the formulas (1) and (2).

$$X = s \cdot Z \tag{1}$$

$$s = \frac{1}{\max_{1 \leq i \leq n} \sum_{j=1}^{n} z_{ij}}, i, j = 1, 2, \cdots, n. \tag{2}$$

Definition 4: The total relation matrix, T, is obtained by the formula (3), in which I represents the identity matrix.

$$T = X(I - X)^{-1}. \tag{3}$$

Definition 5: The row totals and the column totals of the total relation matrix, T, are represented as D and R by the formulas (4)-(6).

$$T = t_{ij}, \quad i,j = 1,2,\ldots,n, \tag{4}$$

$$D = \sum_{j=1}^{n} t_{ij}, \tag{5}$$

$$R = \sum_{i=1}^{n} t_{ij}, \quad (6)$$

where D and R represents the row totals and the column totals, respectively.

Definition 6: A cause-effect diagram can be obtained by graphing the dataset, in which the (D+R) represents the horizontal axis, and is comprised of summing up D with R, and (D-R) represents the vertical axis, and is comprised of subtracting R from D.

3.3.2. CONVERTING FUZZY DATA INTO CRISP SCORES (CFCS)

There are various defuzzification techniques, divided into two categories: vertical or horizontal representation of possibility distribution (Oussalah, 2002). However, Opricovic and Tzeng (2003) stated that, an effective defuzzification technique should take into consideration that the shape, height, spread, and the relative location of x axis are the main characteristics of the fuzzy number.

The most popular defuzzification technique is the Centroid (Center-of-gravity) method (Yager and Filev, 1994), however, this method cannot make a distinction between the same crisp-valued fuzzy numbers, even though they have different shapes Therefore, Converting Fuzzy data into Crisp Scores (CFCS) defuzzification technique is adopted, because it can give better crisp scores than the Centroid method (Wu and Lee, 2007).

The CFCS method is proposed by Opricovic and Tzeng (2003), and its procedure is subject to identifying the left and right scores by fuzzy minimum and fuzzy maximum. The total score is identified by taking a weighted average in accordance with the membership functions. Let $\tilde{z}_{ij}^{k} = (l_{ij}^{k}, m_{ij}^{k}, r_{ij}^{k})$ states the fuzzy judgments of the evaluator *k* (k = 1,2,. . . ,p) about the level of the influence of criterion *i* to criterion *j*. Five-step algorithm is expressed as follows (Opricovic and Tzeng, 2003):

(1) Normalization:

$$xl_{ij}^{k} = (l_{ij}^{k} - \min l_{ij}^{k}) / \Delta_{\min}^{\max}, \tag{7}$$

$$xm_{ij}^{k} = (m_{ij}^{k} - \min l_{ij}^{k}) / \Delta_{\min}^{\max}, \tag{8}$$

$$xr_{ij}^{k} = (r_{ij}^{k} - \min l_{ij}^{k}) / \Delta_{\min}^{\max}, \tag{9}$$

where $\Delta_{\min}^{\max} = \max r_{ij}^{k} - \min l_{ij}^{k}$.

(2) Calculate left and right normalized values:

$$xls_{ij}^{k} = xm_{ij}^{k} /(1 + xm_{ij}^{k} - xl_{ij}^{k}), \tag{10}$$

$$xrs_{ij}^{k} = xr_{ij}^{k} /(1 + xr_{ij}^{k} - xm_{ij}^{k}). \tag{11}$$

(3) Calculate total normalized crisp value:

$$x_{ij}^{k} = \left[xls_{ij}^{k}(1 - xls_{ij}^{k}) + xrs_{ij}^{k} xrs_{ij}^{k}\right] / \left[1 - xls_{ij}^{k} + xrs_{ij}^{k}\right]. \tag{12}$$

(4) Calculate crisp values:

$$z_{ij}^{k} = \min l_{ij}^{k} + x_{ij}^{k} \Delta_{\min}^{\max}. \tag{13}$$

(5) Integrate crisp values:

$$z_{ij}^{k} = \frac{1}{p}(z_{ij}^{1} + z_{ij}^{2} + \cdots + z_{ij}^{p}). \tag{14}$$

3.3.3. THE PROCEDURE OF FUZZY DEMATEL METHOD

Under a fuzzy environment, the analytical procedure of the proposed method is described as follows:

Step 1: Identifying the decision goal and forming a committee: Decision-making process involves the following steps: (1) describing the decision goals, (2) collecting the relevant data, (3) identifying the possible alternatives, (4) assessing the alternatives with regard to their advantages and disadvantages, (5) selecting the best alternative, and (6) monitoring the results whether the decision goals are attained or not (Hess and Siciliano, 1996; Opricovic and Tzeng, 2004). For this reason, the decision-making process starts with determining and describing the decision goals. Another important aspect is to appoint a committee for collecting the group knowledge for problem solving (Wu and Lee, 2007).

Step 2: Developing evaluation criteria and designing the fuzzy linguistic scale: Due to the nature of cause-effect relationships the criteria have, they involve many complex aspects. The DEMATEL method should be used to create a structural model in order to divide the significant criteria into cause group and effect group. To deal with the subjectivity and vagueness of human judgment, the influence of the criteria between each other are expressed in five linguistic terms (Li, 1999) as No Influence (No), Very Low Influence (VL), Low Influence (L), High Influence (H), and Very High Influence (VH). Those linguistic terms are described in positive triangular fuzzy numbers (l_{ij}, m_{ij}, r_{ij}) as shown in Table 3.

Step 3: Acquiring and aggregating the assessments of decision makers: A group of experts are asked to evaluate the influences of criteria to each other in order to measure the relationships between all criteria, that is, C = {C_1, C_2, …, C_n}. Then, those fuzzy evaluations are defuzzified into crisp values, z_{ij}, by CFCS method. As a consequence, the direct relation matrix, $Z = \lfloor z_{ij} \rfloor_{nxn}$, is acquired by the formulas (7)-(14) (Lin and Wu, 2008).

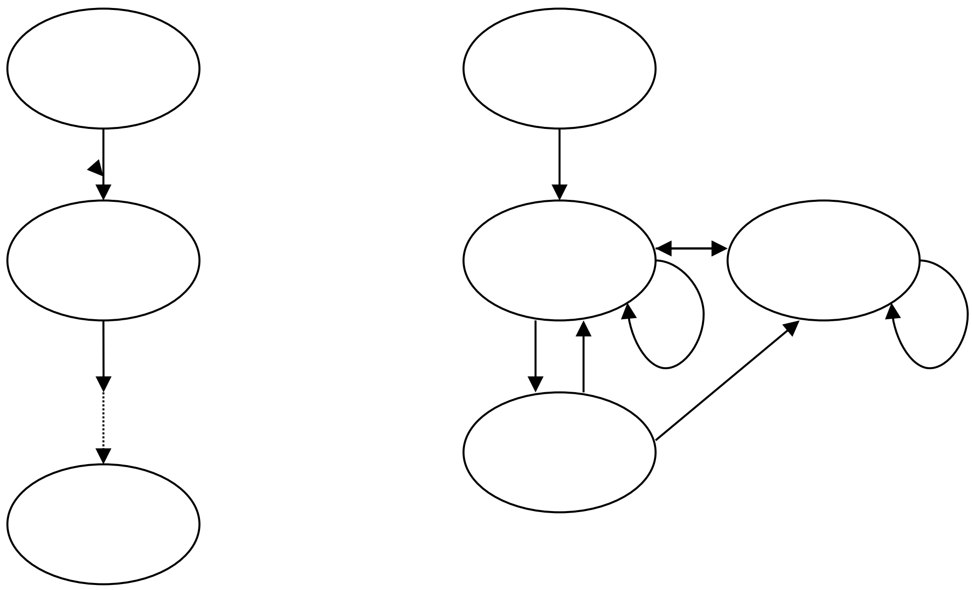
Step 4: Establishing and analyzing the structural model: After gathering the direct relation matrix, Z, by the formulas (1) and (2), the normalized direct relation matrix, X, can be acquired. Then, the total relation matrix, T can be obtained by the formula (3). The row totals and the column totals of the total relation matrix, T, are represented as D and R by the formulas (4)-(6). A cause-effect diagram can be obtained by graphing the dataset, in which the (D+R) represents the horizontal axis, and is comprised of the sums of D with R, and (D-R) represents the vertical axis, and is calculated by subtracting R from D. (D+R) and (D-R) are called "Prominence", and "Relation", respectively. Prominence represents the degree of importance of the criterion, and the Relation distinguishes the criteria as cause and effect criteria. If the (D-R) is positive, then the criterion falls into the cause group, if negative, into the effect group. Hence, the cause-effect diagrams make clear the complex relationships of a set of criteria, and allow the visualization of the structural model. An appropriate decision could be made by determining the cause group and effect group, and distinguishing the differences between cause criteria and the effect criteria based on cause-effect diagrams (Wu and Lee, 2007).

3.4. FUZZY ANALYTICAL NETWORK PROCESS (ANP)

3.4.1. ANP METHOD

The Analytic Network Process (ANP) is the most commonly-used approach for decision-making analysis. Proposed by Saaty (1996), it is formed as a network, rather than a hierarchy, compared with Analytic Hierarchy Process (AHP). Under AHP, the decision-making process is broken down into a top-down linear relationship with independent criteria at each level (Meade and Sarkis, 1999). However, in ANP, there is a relationship between both the clusters (outer dependence), and the criteria within the clusters (inner dependence). In other words, the criterion for a cluster may affect any criterion in same cluster, or any other cluster (Onut et al., 2009). The main aim is to identify the overall importance weights of all criteria.

Hierarchy is sometimes an inappropriate structure for defining a decision problem in which higher-level clusters are dependent on a lower-level clusters (Saaty, 1996). Rather than a hierarchy, a network system is required when there is a feedback between clusters. Saaty (1996) suggested using AHP where the alternatives or criteria are independent, and ANP where they are dependent. The differences of the structures of hierarchies and networks can be seen in Figure 6.



(a) **(b)**

Figure 6: Structural Difference between a Hierarchy and a Network (a) a Hierarchy (b) a Network (Chung et. al., 2005).

The process of modelling contains three major steps (Onut et al., 2009):

Step 1: Pairwise comparisons and priority vectors: Like AHP, in ANP, pairwise comparisons are used to identify the connections and priorities between the criteria and clusters. The clusters and the criteria of each cluster are compared pairwise, based on internal and external dependencies (Chung et al., 2005). Decision-makers weigh the two clusters or two criteria based on their relative importance regarding upper-level cluster or criterion by indicating their assessments, using Saaty's scale (Saaty, 1980). Saaty's scale allows decision-makers determine the relative weights by representing their judgments in linguistic terms as equally important (E), moderately more important (MM), strongly more important (SM), very strongly more important (VSM), and extremely more important (EM) (Chung et al., 2005). The linguistic terms are then converted into numerical values, 1, 3, 5, 7, 9, respectively. The intermediate values, 2, 4, 6, and 8 are used to reflect compromise between the above values. The relative importance of the criterion *i* to criterion *j* is indicated by a score of a_{ij}, i.e., $a_{ij}=w_i/w_j$. A reciprocal value is found by comparing inversely, that is, $a_{ij}=1/a_{ji}$, indicating that criterion *j* is more important than criterion *i* (Onut et al., 2009).

The pairwise comparison matrix, *A*, is defined as follows:

$$A=\begin{bmatrix} w_1/w_1 & w_1/w_2 \cdots w_1/w_n \\ w_2/w_1 & w_2/w_2 \cdots w_2/w_n \\ \vdots & \vdots \quad\quad \vdots \\ w_n/w_1 & w_n/w_2 \cdots w_n/w_n \end{bmatrix}=\begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (15)$$

Likewise in AHP, an eigenvector (local priority vector), w, is calculated by following equation:

$$A\times w=\lambda_{\max}\times w \quad (16)$$

where $\lambda_{\max}$ is the biggest eigenvalue of matrix A.

Step 2: Initial supermatrix formation: As stated by Saaty (1996), a supermatrix is a concept similar to Markov chains process. Saaty (2001) proposed a supermatrix approach as appropriate for reflecting the relationships of the network and acquiring the weights of the criteria. A supermatrix is a segmented matrix in which each matrix part incorporates a relationship (Meade and Sarkis, 1999). Let the clusters of a decision system be $C_k, k = 1,...,n$, and each cluster k has m_k criteria, indicated by $e_{k1}, e_{k2},..., e_{km_k}$. A standard supermatrix is shown as follows (Lee et al., 2008):

$$W = \begin{matrix} C_1 \\ \vdots \\ C_k \\ \vdots \\ C_n \end{matrix} \begin{bmatrix} a_{11} & \dots & a_{1k} & \dots & a_{1n} \\ \vdots & \dots & \vdots & \dots & \vdots \\ a_{k1} & \dots & a_{kk} & \dots & a_{kn} \\ \vdots & \dots & \vdots & \dots & \vdots \\ a_{n1} & \dots & a_{nk} & \dots & a_{nn} \end{bmatrix} \quad (17)$$

For example, a_{k1} block shows the relative importance of cluster k regarding each cluster 1, in other words, it symbolizes the effect of cluster k on each of the cluster 1 (Chung et al., 2005).

Step 3: Weighted Supermatrix formation: An eigenvector is acquired by pairwise comparison of the row criterion with the column criterion. The weighted supermatrix is obtained by weighing the supermatrix by multiplying the first entry of the respective eigenvector with all elements in the first block of that column, second entry with second block, and so on (Chung et al., 2005).

The limit supermatrix, which has the same form with weighted supermatrix, is obtained by taking power of weighted supermatrix to limiting powers in order to sustain the cumulative influence of each criterion on every other criteria interacted (Saaty and Vargas, 1998). The final priorities of all criteria can be found by normalizing each block of the limit supermatrix, in which all the columns are same (Chung et al. 2005).

3.4.2. FUZZY ANP: FUZZY EXTENSION of ANP

In this dissertation, fuzzy logic is integrated to ANP methodology. Triangular fuzzy numbers are used in order to constitute the pairwise comparison matrices. Fuzzy ANP conforms to the relationships between clusters, and criteria with the help of supermatrices to calculate the relative importance weights (Onut et al., 2009).

Although the Saaty's (1980) scale of 1–9 has some advantages like simplicity and easiness for use, decision-makers experience uncertainties in the decision-making process because of the subjective manner of their judgments. Pairwise comparison matrices are constructed by using triangular fuzzy numbers (l, m, r) in which $l \leq m \leq r$. The parameters *l, m,* and *r* indicate the smallest possible value, the most likely value, and the most promising value, respectively. The fuzzy matrix is shown as follows (Onut et al., 2009).

$$\tilde{A} = \begin{pmatrix} (a_{11}^l, a_{11}^m, a_{11}^u) & (a_{12}^l, a_{12}^m, a_{12}^u) & \dots & (a_{1n}^l, a_{1n}^m, a_{1n}^u) \\ (a_{21}^l, a_{21}^m, a_{21}^u) & (a_{22}^l, a_{22}^m, a_{22}^u) & \dots & (a_{2n}^l, a_{2n}^m, a_{2n}^u) \\ \vdots & \vdots & \vdots & \vdots \\ (a_{m1}^l, a_{m1}^m, a_{m1}^u) & (a_{m1}^l, a_{m1}^m, a_{m1}^u) & \dots & (a_{mn}^l, a_{mn}^m, a_{mn}^u) \end{pmatrix} \quad (18)$$

The a_{mn} reflects the pairwise comparison of criterion m (row) with criterion n (column). The pairwise comparison matrix (Ã) is supposed as reciprocal.

$$\tilde{A} = \begin{pmatrix} (1,1,1) & (a_{12}^l, a_{12}^m, a_{12}^u) & \dots & (a_{1n}^l, a_{1n}^m, a_{1n}^u) \\ (\frac{1}{a_{12}^u}, \frac{1}{a_{12}^m}, \frac{1}{a_{12}^l}) & (1,1,1) & \dots & (a_{2n}^l, a_{2n}^m, a_{2n}^u) \\ \vdots & \vdots & \vdots & \vdots \\ (\frac{1}{a_{1n}^u}, \frac{1}{a_{1n}^m}, \frac{1}{a_{1n}^l}) & (\frac{1}{a_{2n}^u}, \frac{1}{a_{2n}^m}, \frac{1}{a_{2n}^l}) & \dots & (1,1,1) \end{pmatrix} \quad (19)$$

Logarithmic least squares method which can be seen as follows can be used to estimate the fuzzy priorities $\tilde{w}_i$ (Chen and Hwang, 1992).

$$\tilde{W} = \left(W_k^l, W_k^m, W_k^u\right) \quad k = 1,2,3,\dots,n$$

where

$$W_k^s = \frac{\left(\prod_{j=1}^{n} a_{kj}^{s}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}^{m}\right)^{1/n}}, \quad s \in \{l, m, u\} \tag{20}$$

3.5. FUZZY ANALYTICAL HIERARCHY PROCESS (AHP)

3.5.1. AHP METHOD

The Analytical Hierarchy Process, proposed by Saaty (1980), is one of the most popular MCDM techniques. It can handle the criteria easily, and can effectively deal with both quantitative and qualitative data. Like ANP, AHP is comprised using pairwise comparisons in order to identify the connections and priorities between the criteria. Decision-makers are able to weigh the two criteria based on their relative importance regarding another criterion, indicating their assessments using Saaty's scale (Saaty, 1980). Saaty's scale enables decision-makers to determine the relative weights by representing their judgments in linguistic terms as equally important (E), moderately more important (MM), strongly more important (SM), very strongly more important (VSM), and extremely more important (EM) (Chung et al., 2005). Linguistic terms are then converted into numerical values, 1, 3, 5, 7, 9, respectively. The intermediate values, 2, 4, 6, and 8 are used to reflect compromise between the above values. The relative importance of the criterion i to criterion j is indicated by a score of a_{ij}, i.e., $a_{ij}=w_i/w_j$. A reciprocal value is found by comparing inversely, that is, $a_{ij}=1/a_{ji}$, indicating that criterion j is more important than criterion i (Onut et al., 2009).

3.5.2. FUZZY AHP: FUZZY EXTENSION of AHP

Fuzzy extension of AHP methodology differs from Saaty's (1980) approach, because it combines fuzzy set theory. In fuzzy AHP, triangular fuzzy numbers are used in order to constitute the pairwise comparison matrices. Fuzzy AHP conforms to the relationships between criteria using supermatrices to obtain the relative importance weights (Onut et al., 2009).

The fuzzy AHP approach is comprised of two steps (Duran and Aguilo, 2008):

1. Building a hierarchy of criteria,

2. Constituting a fuzzy judgment matrix.

Fuzzy judgment vector is attained for each criterion using pairwise comparisons. Although the Saaty's (1980) scale of 1–9 has advantages like simplicity and easiness for use, decision-makers experience uncertainties because of the subjective manner in which they make their judgments. Pairwise comparison matrices are constructed by using triangular fuzzy numbers (l, m, r) in which $l \le m \le r$. The parameters *l*, *m*, and *r* indicate the smallest possible value, the most likely value, and the most promising value, respectively. The fuzzy matrix is shown as follows (Onut et al., 2009).

The fuzzy judgment matrix, $\tilde{A}$, is constructed with all fuzzy judgment vectors (Duran and Aguilo, 2008).

$$\tilde{A} = \begin{pmatrix} (a_{11}^l, a_{11}^m, a_{11}^r) & (a_{12}^l, a_{12}^m, a_{12}^r) & \dots & (a_{1n}^l, a_{1n}^m, a_{1n}^r) \\ (a_{21}^l, a_{21}^m, a_{21}^r) & (a_{22}^l, a_{22}^m, a_{22}^r) & \dots & (a_{2n}^l, a_{2n}^m, a_{2n}^r) \\ \vdots & \vdots & \vdots & \vdots \\ (a_{m1}^l, a_{m1}^m, a_{m1}^r) & (a_{m1}^l, a_{m1}^m, a_{m1}^r) & \dots & (a_{mn}^l, a_{mn}^m, a_{mn}^r) \end{pmatrix} \tag{21}$$

The a_{mn} reflects the pairwise comparison of criterion m (row) with criterion n (column).

Using the scale of equally important (E), moderately more important (MM), strongly more important (SM), very strongly more important (VSM), and extremely more important (EM), we have the comparison matrix, $\tilde{A}$, where a_{ij} elements represent the estimative of the w_i/w_j relation (Duran and Aguilo, 2008).

Next, the eigenvector and the eigenvalue are computed. The fuzzy eigenvector of matrix $\tilde{A}$ can be calculated using the following formula (Duran and Aguilo, 2008):

$$V_i = \left(\prod_{j=1}^{n} \tilde{a}_{ij} \right)^{1/n} \tag{22}$$

Consequently, we now have:

$$V_1 = (\widetilde{a}_{11} x \widetilde{a}_{12} x \widetilde{a}_{13} x ... x \widetilde{a}_{1n})^{1/n} \tag{23}$$

…

$$V_n = (\widetilde{a}_{n1} x \widetilde{a}_{n2} x \widetilde{a}_{n3} x ... x \widetilde{a}_{nn})^{1/n} \tag{24}$$

Eigenvector V_i is compound by the *n* triangular numbers defined as

$$V = (V_1^l, V_1^m, V_1^r; V_2^l, V_2^m, V_2^r; ...; V_n^l, V_n^m, V_n^r) \tag{25}$$

Likewise the traditional AHP, the eigenvector is then normalized by the following formula (Duran and Aguilo, 2008):

$$T = (w_1 / \sum w_i, w_2 / \sum w_i, ..., w_n / \sum w_i) \tag{26}$$

where T is the normalized eigenvector. The weights of the criteria are extracted from this normalized eigenvector.

The result of any AHP analysis is only valid if it is consistent. The consistency ratio is computed by the following formula:

$$CR = CI / RI \tag{27}$$

where RI is Random Consistency Index (RI) created by Saaty (1980), and CI is found by:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{28}$$

If the consistency ratio (CR) is less than 10%, then the result of the AHP analysis is consistent.

CHAPTER 4: APPLICATION

The application was conducted in an elevator and escalator manufacturing firm located in Maltepe, Menemen, Izmir. Five experts from the firm participated in the survey; the general manager, the operations manager, the vice operations manager, the member of the executive board, and the craft supervisor.

4.1. MODEL

The model, which is called hybrid multi criteria decision-making (MCDM) model, consists of different MCDM techniques. Firstly, fuzzy TISM technique was applied in order to determine the relationships between a set of criteria. Then, fuzzy DEMATEL technique was employed to identify the causal relationships. In the next step, with the help of the output of the fuzzy DEMATEL method, inner-dependence matrix, FANP technique is applied in order to determine the weights of sub-criteria. Following this process, the weights of corresponding measurements were found using fuzzy AHP technique. Thus, the structural causal relationship, the weights of sub-criteria, and the weights of the measurements were found. Finally, all found indices were multiplied by the performance indices in order to calculate the overall performance assessment score. In other words, the overall performance assessment score was found by:

$$S = \sum_{i=1}^{k} w_{ij} x w_{ijk} x k_{ijk} \tag{29}$$

where w_{ij} denotes the weights of the sub-criteria, w_{ijk} denotes the weights of the corresponding measurements, and k_{ijk} denotes the corresponding performance indices.

Hervani et al. (2005) pointed out that, the perfect tool for traditional performance measurement systems does not exist, and that their usage is greatly dependent on acceptance by organizations. In other words, there is no perfect tool for generalizing the performance measurements, because the scales and the applications are usually specific to the organizations. Therefore, the model may be generalized; however, the application is unique to the company. In addition, the model may be adapted by other companies to assess their layout performance.

This model is not only used for as an assessment tool, but also for determining the road map. The results will reflect the good as well as the poor performances; therefore, it may also provide a road map for a course of action. It may clear possible further developments, possible savings, and possible efficient usage of resources. The model may give a number of suggestions for possible outcomes.

Microsoft Excel templates have been prepared to solve the algorithms.

4.2. FUZZY TISM

Pairwise comparisons were made with five experts; the general manager, the operations manager, the vice operations manager, the member of the executive board, and the craft supervisor. Each expert made the pairwise comparisons using linguistic variables shown in Table 3. Table 5 shows the pairwise comparison matrix of one of the experts.

Table 6 shows the overall aggregated matrix. Overall aggregated matrix was constructed using mode, in other words, the preferences of the individual experts with highest frequencies were collected.

Then, the overall aggregated SSIM matrix is transformed into a fuzzy reachability matrix as seen in Table 7.

Tables 59-62 in Appendix show the pairwise comparison matrices of Experts 2, 3, 4, and 5, respectively.

According to the results, the relationship diagram is occurred as seen in Figure 7.

Table 5: Pairwise Comparison of Expert 1

EXPERT 1	Other Characteristics	Production Characteristics	Time in non-Production	Time in Production	Sustainability	Maintenance	Property-related Security	Worker-related Comfort	Human-related Safety	Community Environment	Topography and Topology	Routing Flexibility	Volume Flexibility	Robustness	Non-Material Flow	Material Flow	Space Relationship	Inventory Cost
Non-Inventory Cost	X(VH,VL)	X(VH,H)	X(VH)	X(VH,VL)	X(H,VH)	X(VH)	X(H,VH)	X(VH,H)	X(VH,H)	X(VH,L)	X(VH)	X(VL,L)	X(L,H)	A(VL)	X(VH,H)	X(H)	X/H,L)	V(VH)
Inventory Cost	A(L)	A(VH)	A(H)	A(VH)	A(H)	X(H,VH)	X(L,H)	X(VL,H)	A(VH)	A(VL)	A(H)	A(VH)	X(H)	A(VH)	A(H)	A(L)	A/VH)	
Space Relationship	X(H,VH)	X(L,H)	X(H)	X(H)	X(VL,H)	V(VL)	X(L,VH)	X(VH,H)	X(VH,H)	X(L,H)	X(L,H)	X(H,VH)	X(H,VH)	X(VL)	X(VH)	X(VH,H)		
Material Flow	A(L)	X(VH,H)	X(VH,H)	X(VH)	X(H,VH)	X(H,VH)	X(H,VH)	X(VL,L)	X(H)	X(H)	X(H,VH)	X(VH)	X(VH)	X(VH,H)	X(H)			
Non-Material Flow	A(L)	X(H)	X(VH,H)	X(L,VL)	X(H,VH)	X(H,VL)	X(H,VH)	X(VL,L)	X(VH,H)	X(H)	X(H,VH)	X(VH)	X(L,VH)	X(L,VL)				
Robustness	V(L)	X(H,L)	V(VH)	V(VH)	A(VL)	X(H,VH)	A(L)	O(NO)	X(VL)	A(VL)	A(L)	X(VL,L)	X(H)					
Volume Flexibility	X(L)	X(VH,L)	X(VH,L)	X(VH)	X(H,L)	X(H,VH)	X(H,L)	X(H,L)	X(VH,L)	O(NO)	X(L,VL)	X(L,VH)						
Routing Flexibility	V(H)	X(VH,H)	X(VH,H)	X(VH,H)	X(H)	X(H)	X(H,VH)	V(H)	X(L,H)	A(L)	X(L,VL)							
Topography and Topology	O(NO)	O(NO)	V(VH)	V(VL)	X(L,VH)	V(L)	X(H)	V(VH)	V(H)	X(L,H)								
Community Environment	O(NO)	V(VL)	V(H)	V(H)	X(VH)	O(NO)	V(VL)	V(VH)	V(VH)									
Human-related Safety	X(H)	V(VL)	X(H)	X(H,VH)	X(VL,VH)	A(VH)	O(NO)	X(VH)										
Worker-related Comfort	X(H)	V(H)	X(VH,H)	X(H,VH)	X(VL,VH)	A(VH)	O(NO)											
Property-related Security	A(L)	O(NO)	X(VL,VH)	V(L)	A(VH)	A(L)												
Maintenance	X(L,H)	X(H)	X(H)	X(VH,VL)	V(VH)													
Sustainability	X(H,VH)	X(H,L)	V(H)	V(VH)														
Time in Production	X(VH,H)	X(H)	X(H)															
Time in non-Production	X(H,L)	A(L)																
Production Characteristics	X(H)																	

Table 6: Overall Aggregated Matrix

Overall (Aggregated SSIM Matrix)	Other Characteristics	Production Characteristics	Time in non-Production	Time in Production	Sustainability	Maintenance	Property-related Security	Worker-related Comfort	Human-related Safety	Community Environment	Topography and Topology	Routing Flexibility	Volume Flexibility	Robustness	Non-Material Flow	Material Flow	Space Relationship	Inventory Cost
Non-Inventory Cost	X(L,H)	X(VH,H)	X(VH)	X(VH,VL)	X(H)	X(H)	X(L)	X(L)	X(VH,H)	O(NO)	X(VL,H)	X(VL,L)	X(L,H)	A(VL)	X(H,VH)	X(VH)	X(H,L)	X(H)
Inventory Cost	A(L)	X(L,H)	A(H)	A(VH)	A(H)	X(H)	X(L,H)	X(VL,H)	O(NO)	A(VL)	O(NO)	A(L)	X(H)	A(VH)	A(H)	A(L)	A(VH)	
Space Relationship	X(L,H)	X(L,H)	X(H)	X(VH,H)	A(L)	X(H,L)	X(L,VH)	X(L)	A(L)	X(L,H)	X(L,H)	X(H,VH)	X(H,VH)	X(VL)	X(H,VH)	X(VH)		
Material Flow	X(L,H)	X(H)	X(H)	X(L,H)	X(H)	V(L)	A(H)	A(L)	X(H)	A(L)	X(L,H)	X(H,VH)	X(H,VH)	X(H)	X(H)			
Non-Material Flow	A(H)	X(H)	X(H)	X(L,VL)	X(L,H)	O(NO)	A(H)	X(H)	X(H)	X(H)	X(L,H)	X(L,H)	X(L,VH)	X(L,VL)				
Robustness	V(L)	X(H,L)	X(VH,L)	V(VH)	A(L)	X(H)	A(L)	O(NO)	X(VL)	A(VL)	A(L)	X(VL,L)	X(H)					
Volume Flexibility	V(L)	X(VH,L)	X(VH,L)	X(VH)	X(H,L)	X(H,L)	X(H,L)	X(H,L)	X(VH,L)	O(NO)	X(L)	X(L,VH)						
Routing Flexibility	V(H)	X(H)	X(VH,H)	X(VH,H)	X(H)	X(L)	A(H)	V(L)	X(L,H)	A(L)	X(L)							
Topography and Topology	A(H)	X(VL,L)	V(H)	V(VL)	X(L,H)	A(L)	X(H)	X(L)	V(H)	X(L,H)								
Community Environment	O(NO)	X(VL,L)	V(H)	V(H)	X(L,H)	A(L)	V(VL)	X(H)	V(VH)									
Human-related Safety	X(H)	X(L,H)	X(H)	X(H)	X(L,H)	A(H)	O(NO)	X(H)										
Worker-related Comfort	X(H)	X(H)	X(VH,H)	X(H)	X(L,H)	A(H)	O(NO)											
Property-related Security	A(L)	O(NO)	X(L,H)	V(L)	A(H)	A(L)												
Maintenance	X(L,H)	X(H)	X(H)	X(H,VL)	X(H)													
Sustainability	X(L,H)	X(H,VL)	X(H,L)	V(H)														
Time in Production	X(VH,L)	X(H)	X(H)															
Time in non-Production	X(H,L)	A(L)																
Production Characteristics	X(L)																	

Table 7: Fuzzy Reachability Matrix

Final Fuzzy Reachability Matrix	Non-Inventory Cost			Inventory Cost			Space Relationship			Material Flow			Non-Material Flow			Robustness		
Non-Inventory Cost	1	1	1	0.5	0.75	1	0.5	0.75	1	0.75	1	1	0.5	0.75	1	0	0	0.25
Inventory Cost	0.5	0.75	1	1	1	1	0	0	0.25	0	0	0.25	0	0	0.25	0	0	0.25
Space Relationship	0.25	0.5	0.75	0.75	1	1	1	1	1	0.75	1	1	0.5	0.75	1	0	0.25	0.5
Material Flow	0.75	1	1	0.25	0.5	0.75	0.75	1	1	1	1	1	0.5	0.75	1	0.5	0.75	1
Non-Material Flow	0.75	1	1	0.5	0.75	1	0.75	1	1	0.5	0.75	1	1	1	1	0.25	0.5	0.75
Robustness	0	0.25	0.5	0.75	1	1	0	0.25	0.5	0.5	0.75	1	0	0.25	0.5	1	1	1
Volume Flexibility	0.5	0.75	1	0.5	0.75	1	0.75	1	1	0.75	1	1	0.75	1	1	0.5	0.75	1
Routing Flexibility	0.25	0.5	0.75	0.25	0.5	0.75	0.75	1	1	0.75	1	1	0.5	0.75	1	0.25	0.5	0.75
Topography and Topology	0.5	0.75	1	0	0	0.25	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75
Community Environment	0	0	0.25	0	0.25	0.5	0.5	0.75	1	0.25	0.5	0.75	0.5	0.75	1	0	0.25	0.5
Human-related Safety	0.5	0.75	1	0	0	0.25	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0	0.25	0.5
Worker-related Comfort	0.25	0.5	0.75	0.5	0.75	1	0	0	0.25	0.25	0.5	0.75	0.5	0.75	1	0	0	0.25
Property-related Security	0.25	0.5	0.75	0.5	0.75	1	0.75	1	1	0.5	0.75	1	0.5	0.75	1	0	0.25	0.5
Maintenance	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	0	0	0.25	0	0	0.25	0.5	0.75	1
Sustainability	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0	0.25	0.5
Time in Production	0	0.25	0.5	0.75	1	1	0.5	0.75	1	0.5	0.75	1	0	0.25	0.5	0	0	0.25
Time in non-Production	0.75	1	1	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75
Production Characteristics	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75
Other Characteristics	0.5	0.75	1	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0	0	0.25
DEPENDENCE	**8.25**	**12.5**	**16.25**	**8.5**	**12.5**	**16.25**	**9**	**13**	**16.25**	**9.5**	**13.5**	**17**	**8.25**	**12.25**	**16.5**	**3.75**	**7**	**11.5**
CRISP	**12.17506308**			**12.30200277**			**13.03321437**			**13.90603423**			**11.99117441**			**6.097991706**		

Table 7: Fuzzy Reachability Matrix (cont'd)

Final Fuzzy Reachability Matrix (cont'd)	Volume Flexibility			Routing Flexibility			Topography and Topology			Community Environment			Human-related Safety			Worker-related Comfort		
Non-Inventory Cost	0.25	0.5	0.75	0	0.25	0.5	0	0.25	0.5	0	0	0.25	0.75	1	1	0.25	0.5	0.75
Inventory Cost	0.5	0.75	1	0	0	0.25	0	0	0.25	0	0	0.25	0	0	0.25	0	0.25	0.5
Space Relationship	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	0.25	0.5	0.75	0	0	0.25	0	0	0.25
Material Flow	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	0	0	0.25	0.5	0.75	1	0	0	0.25
Non-Material Flow	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1
Robustness	0.5	0.75	1	0	0.25	0.5	0	0	0.25	0	0	0.25	0	0.25	0.5	0	0	0.25
Volume Flexibility	1	1	1	0.25	0.5	0.75	0.25	0.5	0.75	0	0	0.25	0.75	1	1	0.5	0.75	1
Routing Flexibility	0.75	1	1	1	1	1	0.25	0.5	0.75	0	0	0.25	0.25	0.5	0.75	0.25	0.5	0.75
Topography and Topology	0.25	0.5	0.75	0.25	0.5	0.75	1	1	1	0.25	0.5	0.75	0.5	0.75	1	0.25	0.5	0.75
Community Environment	0	0	0.25	0.25	0.5	0.75	0.5	0.75	1	1	1	1	0.75	1	1	0.5	0.75	1
Human-related Safety	0.25	0.5	0.75	0.5	0.75	1	0	0	0.25	0	0	0.25	1	1	1	0.5	0.75	1
Worker-related Comfort	0.25	0.5	0.75	0	0	0.25	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	1	1	1
Property-related Security	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0	0	0.25	0	0	0.25	0	0	0.25
Maintenance	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1
Sustainability	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1
Time in Production	0.75	1	1	0.5	0.75	1	0	0	0.25	0	0	0.25	0.5	0.75	1	0.5	0.75	1
Time in non-Production	0.25	0.5	0.75	0.5	0.75	1	0	0	0.25	0	0	0.25	0.5	0.75	1	0.5	0.75	1
Production Characteristics	0.25	0.5	0.75	0.5	0.75	1	0.25	0.5	0.75	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1
Other Characteristics	0	0	0.25	0	0	0.25	0.5	0.75	1	0	0	0.25	0.5	0.75	1	0.5	0.75	1
DEPENDENCE	**7**	**11**	**15**	**6.25**	**10**	**14.5**	**5**	**8.25**	**12.75**	**3.5**	**5.25**	**9.75**	**8.5**	**12.25**	**16**	**6.75**	**10.25**	**14.75**
CRISP	**10.16414141**			**9.057650529**			**7.224809193**			**4.94345202**			**12.04077956**			**9.439161018**		

Table 7: Fuzzy Reachability Matrix (cont'd)

Final Fuzzy Reachability Matrix	Property-related Security			Maintenance			Sustainability			Time in Production			Time in non-Production			Production Characteristics			Other Characteristics			**DRIVING POWER**			**CRISP**
Non-Inventory Cost	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0.75	1	1	0.75	1	1	0.75	1	1	0.25	0.5	0.75	**8.25**	**12.25**	**15.5**	**11.910962**
Inventory Cost	0.25	0.5	0.75	0.5	0.75	1	0	0	0.25	0	0	0.25	0	0	0.25	0.25	0.5	0.75	0	0	0.25	**3**	**4.5**	**9**	**4.2782204**
Space Relationship	0	0	0.25	0.5	0.75	1	0	0	0.25	0.75	1	1	0.5	0.75	1	0.25	0.5	0.75	0.25	0.5	0.75	**7**	**10.5**	**14.25**	**9.6370755**
Material Flow	0	0	0.25	0.25	0.5	0.75	0.5	0.75	1	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	**7.75**	**11.5**	**15.5**	**11.009665**
Non-Material Flow	0	0	0.25	0	0	0.25	0.25	0.5	0.75	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0	0	0.25	**7.5**	**11.25**	**15.25**	**10.643989**
Robustness	0	0	0.25	0.5	0.75	1	0	0	0.25	0.75	1	1	0.75	1	1	0.5	0.75	1	0.25	0.5	0.75	**5.5**	**8.75**	**12.5**	**7.5178944**
Volume Flexibility	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.75	1	1	0.75	1	1	0.75	1	1	0.25	0.5	0.75	**10.5**	**14.75**	**17.5**	**16.029277**
Routing Flexibility	0	0	0.25	0.25	0.5	0.75	0.5	0.75	1	0.75	1	1	0.75	1	1	0.5	0.75	1	0.5	0.75	1	**8.5**	**12.5**	**15.75**	**12.30965**
Topography and Topology	0.5	0.75	1	0	0	0.25	0.25	0.5	0.75	0	0.25	0.5	0.5	0.75	1	0	0.25	0.5	0	0	0.25	**6**	**9.75**	**14.25**	**8.7409274**
Community Environment	0	0.25	0.5	0	0	0.25	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0	0.25	0.5	0	0	0.25	**5.5**	**9**	**13.25**	**7.8624625**
Human-related Safety	0	0	0.25	0	0	0.25	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	0.5	0.75	1	**6**	**9.25**	**13.75**	**8.265932**
Worker-related Comfort	0	0	0.25	0	0	0.25	0.25	0.5	0.75	0.5	0.75	1	0.75	1	1	0.5	0.75	1	0.5	0.75	1	**6.5**	**9.75**	**14**	**8.8292619**
Property-related Security	1	1	1	0	0	0.25	0	0	0.25	0.25	0.5	0.75	0.25	0.5	0.75	0	0	0.25	0	0	0.25	**5.25**	**8**	**12.25**	**6.913036**
Maintenance	0.25	0.5	0.75	1	1	1	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	**7.25**	**11.25**	**15.75**	**10.629884**
Sustainability	0.5	0.75	1	0.5	0.75	1	1	1	1	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	**8.75**	**13.25**	**17.75**	**13.408681**
Time in Production	0	0	0.25	0	0.25	0.5	0	0	0.25	1	1	1	0.5	0.75	1	0.5	0.75	1	0.75	1	1	**6.75**	**10**	**13.75**	**9.0486258**
Time in non-Production	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	0.5	0.75	1	1	1	1	0	0	0.25	0.5	0.75	1	**8**	**11.75**	**16**	**11.425061**
Production Characteristics	0	0	0.25	0.5	0.75	1	0	0.25	0.5	0.5	0.75	1	0.25	0.5	0.75	1	1	1	0.25	0.5	0.75	**7.5**	**11.75**	**16.25**	**11.239549**
Other Characteristics	0.25	0.5	0.75	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	0.25	0.5	0.75	0.25	0.5	0.75	1	1	1	**6.75**	**10.25**	**14.75**	**9.4488344**
DEPENDENCE	**4**	**6.25**	**10.75**	**6**	**9**	**13.5**	**5.5**	**8.75**	**13.25**	**9.25**	**13.5**	**16.75**	**10**	**14.25**	**17.5**	**7.5**	**11.5**	**15.5**	**5.75**	**9**	**13.25**				
CRISP	**5.586478639**			**8.065262269**			**7.741007131**			**13.71450876**			**15.01619819**			**10.85353535**			**7.958676425**						

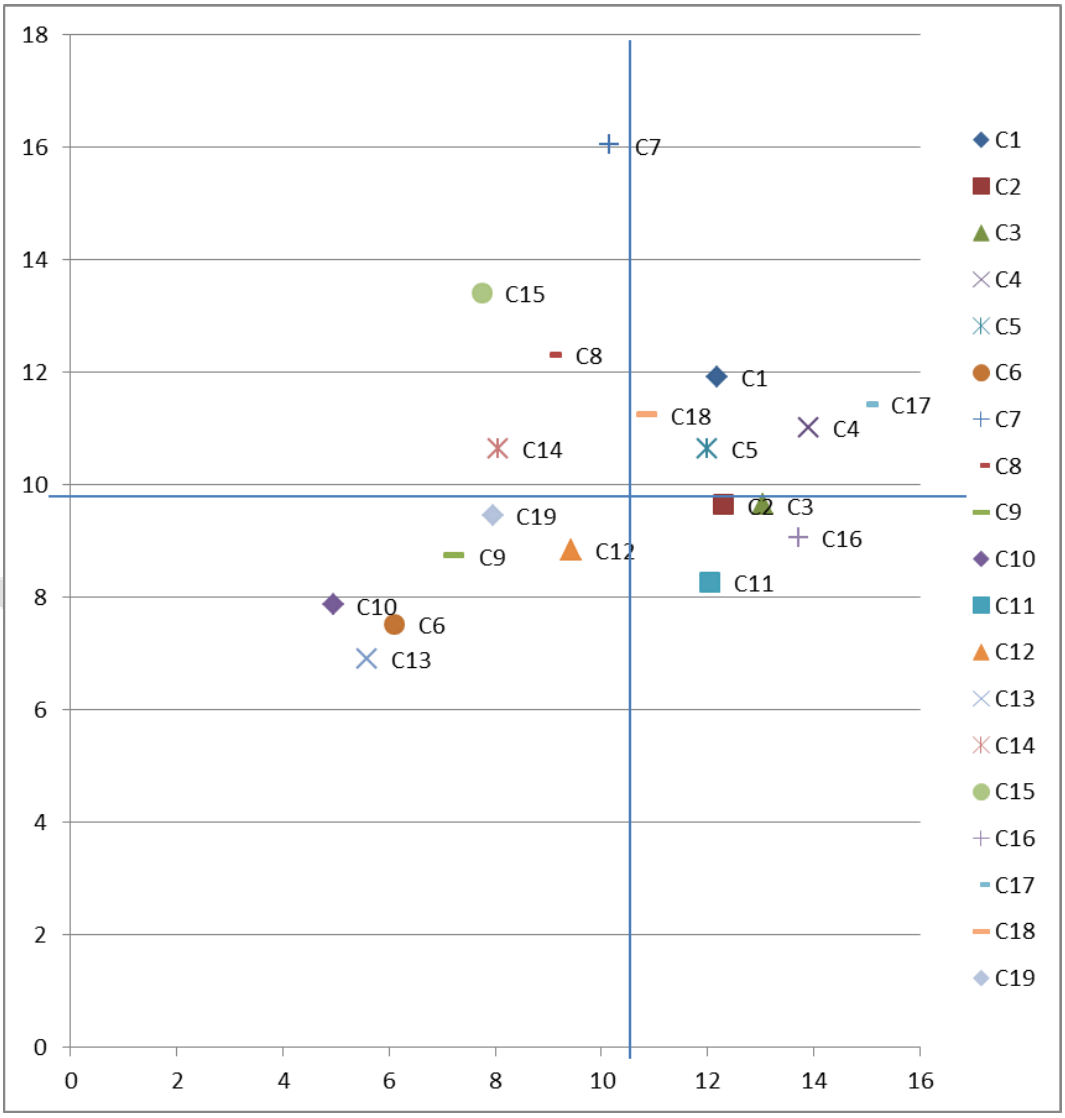


Figure 7: Fuzzy TISM Graph

According to this result;

1) Robustness (C6), Topography and Topology (C9), Community Environment (C10), Worker-related Comfort (C12), Property-related Security (C13), and Other Characteristics (C19) belong to the Autonomous group (I) which are situated in the south-west frame, and have few links with the system. They appear quite out of line with the system. This group denotes weak driving power and weak dependence.

2) Inventory Cost (C2), Space Relationship (C3), Human-related Safety (C11), and Time in Production (C16) belong to the Dependent Group (II), located in the

south-east frame of the chart, are at the same time little influent and very dependent. The group denotes weak driving power and strong dependence.

3) Non-inventory Cost (C1), Material Flow (C4), Non-material Flow (C5), Time in Non-Production (C17), and Production Characteristics (C18) belong to the Linkage group (III) situated in the north-east frame of the chart and are at the same time very influent and very dependent. The group denotes strong driving power and strong dependence.

4) Volume Flexibility (C7), Routing Flexibility (C8), Maintenance (C14), and Sustainability (C15) belong to the Independent Group (IV), located in the north-west frame of the perception chart, are very influent and little dependent. The group denotes strong driving power and weak dependence.

4.3. FUZZY DEMATEL

Pairwise comparisons were made with five experts; the general manager, the operations manager, the vice operations manager, the member of the executive board, and the craft supervisor. Each expert made the pairwise comparisons using linguistic variables shown in Table 3. Table 8 shows the pairwise comparison matrix of one of the experts.

Table 9 shows the direct relation matrix, Z, table 10 shows the normalized direct relation matrix, X, and table 11 shows the total relation matrix, T, respectively.

Tables 63-66 in Appendix show the pairwise comparison matrices of Experts 2, 3, 4, and 5, respectively.

Table 8: Pairwise Comparison of Expert 1

EXPERT 1	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	NO	VH	H	H	VH	NO	L	VL	VH	VH	VH	VH	H	VH	H	VH	VH	VH	VH
Inventory Cost	NO	NO	NO	NO	NO	NO	H	NO	NO	NO	NO	VL	L	H	NO	NO	NO	NO	NO
Space Relationship	L	VH	NO	VH	VH	VL	H	H	L	L	VH	VH	L	VL	VL	H	H	L	H
Material Flow	H	L	H	NO	H	VH	VH	VH	H	H	H	VL	H	H	H	VH	VH	VH	NO
Non-Material Flow	H	H	VH	H	NO	L	L	VH	H	H	VH	VL	H	H	H	L	VH	H	NO
Robustness	VL	VH	VL	H	VL	NO	H	VL	NO	NO	VL	NO	NO	H	NO	VH	VH	H	L
Volume Flexibility	H	H	VH	VH	VH	H	NO	L	L	NO	VH	H	H	H	H	VH	VH	VH	L
Routing Flexibility	L	VH	VH	VH	VH	L	VH	NO	L	NO	L	H	H	H	H	VH	VH	VH	H
Topography and Topology	VH	H	H	VH	VH	L	VL	VL	NO	L	H	VH	H	L	L	VL	VH	NO	NO
Community Environment	L	VL	H	H	H	VL	NO	L	H	NO	VH	VH	VL	NO	VH	H	H	VL	NO
Human-related Safety	H	VH	H	H	H	VL	L	H	NO	NO	NO	VH	NO	NO	VL	H	H	VL	H
Worker-related Comfort	H	H	H	L	L	NO	L	NO	NO	NO	VH	NO	NO	NO	VL	H	VH	H	H
Property-related Security	VH	H	VH	VH	VH	L	L	VH	H	NO	NO	NO	NO	NO	NO	L	VL	NO	NO
Maintenance	VH	VH	NO	VH	VL	VH	VH	H	NO	NO	VH	VH	L	NO	VH	VH	H	H	L
Sustainability	VH	H	H	VH	VH	VL	L	H	VH	VH	VH	VH	VH	NO	NO	VH	H	H	H
Time in Production	VL	VH	H	VH	VL	NO	VH	H	NO	NO	VH	VH	NO	VL	NO	NO	H	H	VH
Time in non-Production	VH	H	H	H	H	NO	L	H	NO	NO	H	H	VH	H	NO	H	NO	NO	H
Production Characteristics	H	VH	H	H	H	L	L	H	NO	NO	NO	NO	NO	H	L	H	L	NO	H
Other Characteristics	VL	L	VH	L	L	NO	L	NO	NO	NO	H	H	L	H	VH	H	L	H	NO

Table 9: Direct Relation Matrix, Z

Z	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	0.03333	0.78000	0.78000	0.82667	0.82667	0.17333	0.50000	0.36000	0.59333	0.54667	0.73333	0.68667	0.59333	0.78000	0.73333	0.87333	0.92000	0.82667	0.59333
Inventory Cost	0.54667	0.03333	0.45333	0.22000	0.03333	0.12667	0.64000	0.03333	0.03333	0.03333	0.03333	0.17333	0.50000	0.59333	0.12667	0.22000	0.31333	0.31333	0.03333
Space Relationship	0.59333	0.92000	0.03333	0.87333	0.78000	0.45333	0.73333	0.73333	0.54667	0.59333	0.40667	0.59333	0.31333	0.54667	0.26667	0.87333	0.82667	0.59333	0.54667
Material Flow	0.87333	0.36000	0.87333	0.03333	0.73333	0.68667	0.82667	0.82667	0.59333	0.31333	0.54667	0.17333	0.31333	0.59333	0.73333	0.64000	0.82667	0.78000	0.31333
Non-Material Flow	0.87333	0.45333	0.92000	0.73333	0.03333	0.50000	0.36000	0.78000	0.59333	0.31333	0.59333	0.54667	0.31333	0.45333	0.59333	0.54667	0.82667	0.64000	0.03333
Robustness	0.26667	0.92000	0.40667	0.68667	0.22000	0.03333	0.78000	0.45333	0.12667	0.03333	0.36000	0.12667	0.03333	0.68667	0.17333	0.82667	0.87333	0.82667	0.36000
Volume Flexibility	0.82667	0.73333	0.87333	0.96667	0.73333	0.59333	0.03333	0.59333	0.40667	0.03333	0.54667	0.45333	0.54667	0.54667	0.73333	0.82667	0.96667	0.87333	0.50000
Routing Flexibility	0.68667	0.50000	0.87333	0.96667	0.73333	0.59333	0.87333	0.03333	0.50000	0.03333	0.50000	0.50000	0.31333	0.50000	0.73333	0.82667	0.92000	0.82667	0.64000
Topography and Topology	0.82667	0.31333	0.68667	0.82667	0.82667	0.26667	0.45333	0.45333	0.03333	0.31333	0.64000	0.73333	0.45333	0.36000	0.50000	0.45333	0.78000	0.22000	0.08000
Community Environment	0.22000	0.17333	0.68667	0.40667	0.45333	0.17333	0.17333	0.36000	0.45333	0.03333	0.82667	0.82667	0.26667	0.12667	0.73333	0.45333	0.40667	0.36000	0.12667
Human-related Safety	0.64000	0.40667	0.59333	0.73333	0.73333	0.36000	0.31333	0.73333	0.22000	0.26667	0.03333	0.82667	0.17333	0.17333	0.40667	0.73333	0.73333	0.40667	0.64000
Worker-related Comfort	0.59333	0.40667	0.59333	0.59333	0.64000	0.26667	0.50000	0.22000	0.26667	0.36000	0.78000	0.03333	0.03333	0.03333	0.40667	0.64000	0.73333	0.64000	0.64000
Property-related Security	0.73333	0.64000	0.59333	0.87333	0.73333	0.50000	0.50000	0.82667	0.78000	0.22000	0.22000	0.22000	0.03333	0.22000	0.17333	0.36000	0.45333	0.12667	0.12667
Maintenance	0.78000	0.78000	0.31333	0.36000	0.17333	0.68667	0.64000	0.54667	0.31333	0.31333	0.73333	0.73333	0.59333	0.03333	0.78000	0.78000	0.68667	0.73333	0.50000
Sustainability	0.82667	0.82667	0.59333	0.82667	0.78000	0.54667	0.59333	0.68667	0.78000	0.78000	0.78000	0.78000	0.78000	0.54667	0.03333	0.78000	0.78000	0.73333	0.54667
Time in Production	0.50000	0.96667	0.73333	0.87333	0.40667	0.31333	0.82667	0.73333	0.03333	0.03333	0.68667	0.68667	0.03333	0.40667	0.17333	0.03333	0.73333	0.64000	0.82667
Time in non-Production	0.92000	0.64000	0.82667	0.78000	0.73333	0.31333	0.59333	0.73333	0.08000	0.08000	0.64000	0.54667	0.64000	0.64000	0.45333	0.68667	0.03333	0.36000	0.73333
Production Characteristics	0.73333	0.82667	0.73333	0.78000	0.73333	0.31333	0.59333	0.64000	0.36000	0.36000	0.54667	0.50000	0.36000	0.82667	0.40667	0.82667	0.40667	0.03333	0.54667
Other Characteristics	0.50000	0.54667	0.82667	0.64000	0.64000	0.22000	0.22000	0.03333	0.45333	0.31333	0.59333	0.64000	0.50000	0.64000	0.78000	0.59333	0.59333	0.59333	0.03333

Table 10: Normalized Direct Relation Matrix, X

X	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	0.00256	0.06000	0.06000	0.06359	0.06359	0.01333	0.03846	0.02769	0.04564	0.04205	0.05641	0.05282	0.04564	0.06000	0.05641	0.06718	0.07077	0.06359	0.04564
Inventory Cost	0.04205	0.00256	0.03487	0.01692	0.00256	0.00974	0.04923	0.00256	0.00256	0.00256	0.00256	0.01333	0.03846	0.04564	0.00974	0.01692	0.02410	0.02410	0.00256
Space Relationship	0.04564	0.07077	0.00256	0.06718	0.06000	0.03487	0.05641	0.05641	0.04205	0.04564	0.03128	0.04564	0.02410	0.04205	0.02051	0.06718	0.06359	0.04564	0.04205
Material Flow	0.06718	0.02769	0.06718	0.00256	0.05641	0.05282	0.06359	0.06359	0.04564	0.02410	0.04205	0.01333	0.02410	0.04564	0.05641	0.04923	0.06359	0.06000	0.02410
Non-Material Flow	0.06718	0.03487	0.07077	0.05641	0.00256	0.03846	0.02769	0.06000	0.04564	0.02410	0.04564	0.04205	0.02410	0.03487	0.04564	0.04205	0.06359	0.04923	0.00256
Robustness	0.02051	0.07077	0.03128	0.05282	0.01692	0.00256	0.06000	0.03487	0.00974	0.00256	0.02769	0.00974	0.00256	0.05282	0.01333	0.06359	0.06718	0.06359	0.02769
Volume Flexibility	0.06359	0.05641	0.06718	0.07436	0.05641	0.04564	0.00256	0.04564	0.03128	0.00256	0.04205	0.03487	0.04205	0.04205	0.05641	0.06359	0.07436	0.06718	0.03846
Routing Flexibility	0.05282	0.03846	0.06718	0.07436	0.05641	0.04564	0.06718	0.00256	0.03846	0.00256	0.03846	0.03846	0.02410	0.03846	0.05641	0.06359	0.07077	0.06359	0.04923
Topography and Topology	0.06359	0.02410	0.05282	0.06359	0.06359	0.02051	0.03487	0.03487	0.00256	0.02410	0.04923	0.05641	0.03487	0.02769	0.03846	0.03487	0.06000	0.01692	0.00615
Community Environment	0.01692	0.01333	0.05282	0.03128	0.03487	0.01333	0.01333	0.02769	0.03487	0.00256	0.06359	0.06359	0.02051	0.00974	0.05641	0.03487	0.03128	0.02769	0.00974
Human-related Safety	0.04923	0.03128	0.04564	0.05641	0.05641	0.02769	0.02410	0.05641	0.01692	0.02051	0.00256	0.06359	0.01333	0.01333	0.03128	0.05641	0.05641	0.03128	0.04923
Worker-related Comfort	0.04564	0.03128	0.04564	0.04564	0.04923	0.02051	0.03846	0.01692	0.02051	0.02769	0.06000	0.00256	0.00256	0.00256	0.03128	0.04923	0.05641	0.04923	0.04923
Property-related Security	0.05641	0.04923	0.04564	0.06718	0.05641	0.03846	0.03846	0.06359	0.06000	0.01692	0.01692	0.01692	0.00256	0.01692	0.01333	0.02769	0.03487	0.00974	0.00974
Maintenance	0.06000	0.06000	0.02410	0.02769	0.01333	0.05282	0.04923	0.04205	0.02410	0.02410	0.05641	0.05641	0.04564	0.00256	0.06000	0.06000	0.05282	0.05641	0.03846
Sustainability	0.06359	0.06359	0.04564	0.06359	0.06000	0.04205	0.04564	0.05282	0.06000	0.06000	0.06000	0.06000	0.06000	0.04205	0.00256	0.06000	0.06000	0.05641	0.04205
Time in Production	0.03846	0.07436	0.05641	0.06718	0.03128	0.02410	0.06359	0.05641	0.00256	0.00256	0.05282	0.05282	0.00256	0.03128	0.01333	0.00256	0.05641	0.04923	0.06359
Time in non-Production	0.07077	0.04923	0.06359	0.06000	0.05641	0.02410	0.04564	0.05641	0.00615	0.00615	0.04923	0.04205	0.04923	0.04923	0.03487	0.05282	0.00256	0.02769	0.05641
Production Characteristics	0.05641	0.06359	0.05641	0.06000	0.05641	0.02410	0.04564	0.04923	0.02769	0.02769	0.04205	0.03846	0.02769	0.06359	0.03128	0.06359	0.03128	0.00256	0.04205
Other Characteristics	0.03846	0.04205	0.06359	0.04923	0.04923	0.01692	0.01692	0.00256	0.03487	0.02410	0.04564	0.04923	0.03846	0.04923	0.06000	0.04564	0.04564	0.04564	0.00256

Table 11: Total Relation Matrix, T

T	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topografy and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	0.19944	0.24038	0.25776	0.26839	0.23783	0.13043	0.20488	0.18934	0.15787	0.12303	0.21725	0.20720	0.15612	0.20243	0.19706	0.25693	0.27238	0.23172	0.17665
Inventory Cost	0.11711	0.07612	0.11065	0.09800	0.07170	0.05609	0.11344	0.06631	0.04771	0.03453	0.06559	0.07275	0.08221	0.10169	0.06554	0.09283	0.10373	0.09107	0.05512
Space Relationship	0.22375	0.23515	0.18792	0.25479	0.21877	0.14096	0.20922	0.20122	0.14371	0.11686	0.17981	0.18585	0.12586	0.17509	0.15282	0.24129	0.25013	0.20288	0.16214
Material Flow	0.24920	0.20259	0.25354	0.20160	0.22214	0.16195	0.22054	0.21445	0.15194	0.10075	0.19432	0.16105	0.13011	0.18381	0.18977	0.23252	0.25716	0.22179	0.15034
Non-Material Flow	0.23222	0.19184	0.23917	0.23392	0.15596	0.13772	0.17317	0.19699	0.14182	0.09437	0.18368	0.17400	0.11927	0.15962	0.16648	0.20840	0.23886	0.19585	0.11889
Robustness	0.15483	0.19545	0.16722	0.19205	0.13532	0.08288	0.17498	0.14379	0.08398	0.05559	0.13646	0.11440	0.08029	0.15364	0.11080	0.19368	0.20409	0.17981	0.11983
Volume Flexibility	0.25531	0.23767	0.26240	0.27757	0.22944	0.16017	0.17100	0.20485	0.14308	0.08412	0.20036	0.18605	0.15164	0.18739	0.19459	0.25318	0.27503	0.23540	0.16967
Routing Flexibility	0.24390	0.21934	0.26140	0.27647	0.22865	0.15955	0.23040	0.16205	0.14876	0.08335	0.19664	0.18870	0.13380	0.18277	0.19450	0.25226	0.27099	0.23164	0.17916
Topografy and Topology	0.21528	0.16646	0.20862	0.22496	0.20148	0.11247	0.16568	0.16219	0.09307	0.08863	0.17570	0.17605	0.12099	0.14025	0.15001	0.18632	0.22074	0.15266	0.11123
Community Environment	0.13733	0.12495	0.17368	0.15949	0.14479	0.08503	0.11616	0.12739	0.10447	0.05467	0.16215	0.15831	0.08712	0.09680	0.14113	0.15328	0.15787	0.13229	0.09286
Human-related Safety	0.19760	0.17123	0.19978	0.21500	0.19117	0.11654	0.15365	0.17753	0.10419	0.08288	0.12858	0.18021	0.09799	0.12594	0.14126	0.20369	0.21378	0.16468	0.15135
Worker-related Comfort	0.18202	0.15991	0.18715	0.19182	0.17382	0.10158	0.15483	0.13111	0.09992	0.08514	0.17307	0.11355	0.08162	0.10721	0.13195	0.18487	0.19992	0.16939	0.14265
Property-related Security	0.19206	0.17481	0.18565	0.21116	0.17878	0.12003	0.15688	0.17439	0.13855	0.07284	0.12955	0.12381	0.08082	0.12017	0.11463	0.16269	0.18065	0.13187	0.10086
Maintenance	0.22497	0.21721	0.19573	0.20721	0.16589	0.15046	0.19268	0.17812	0.12045	0.09323	0.19383	0.18765	0.14025	0.12862	0.17939	0.22478	0.22792	0.20290	0.15365
Sustainability	0.26706	0.25299	0.25624	0.28080	0.24478	0.16335	0.22102	0.22073	0.17801	0.14336	0.22931	0.22166	0.17472	0.19354	0.15404	0.26112	0.27489	0.23501	0.17972
Time in Production	0.19440	0.21816	0.21547	0.23034	0.17200	0.11738	0.19658	0.18117	0.09263	0.06694	0.17936	0.17337	0.09283	0.14939	0.12927	0.15901	0.21960	0.18747	0.16930
Time in non-Production	0.23931	0.20949	0.23695	0.24079	0.20962	0.12719	0.19228	0.19549	0.10801	0.07846	0.18909	0.17621	0.14554	0.17606	0.16025	0.22146	0.18490	0.18028	0.17159
Production Characteristics	0.22466	0.22131	0.22873	0.23840	0.20714	0.12621	0.19152	0.18743	0.12627	0.09796	0.18225	0.17288	0.12447	0.18841	0.15627	0.22981	0.21120	0.15436	0.15652
Other Characteristics	0.19037	0.18395	0.21589	0.20901	0.18555	0.10785	0.14757	0.13008	0.12339	0.08961	0.17128	0.16949	0.12466	0.16026	0.16809	0.19462	0.20400	0.17728	0.10585

According to the results, the cause-effect diagram is occurred as seen in Figure 8.

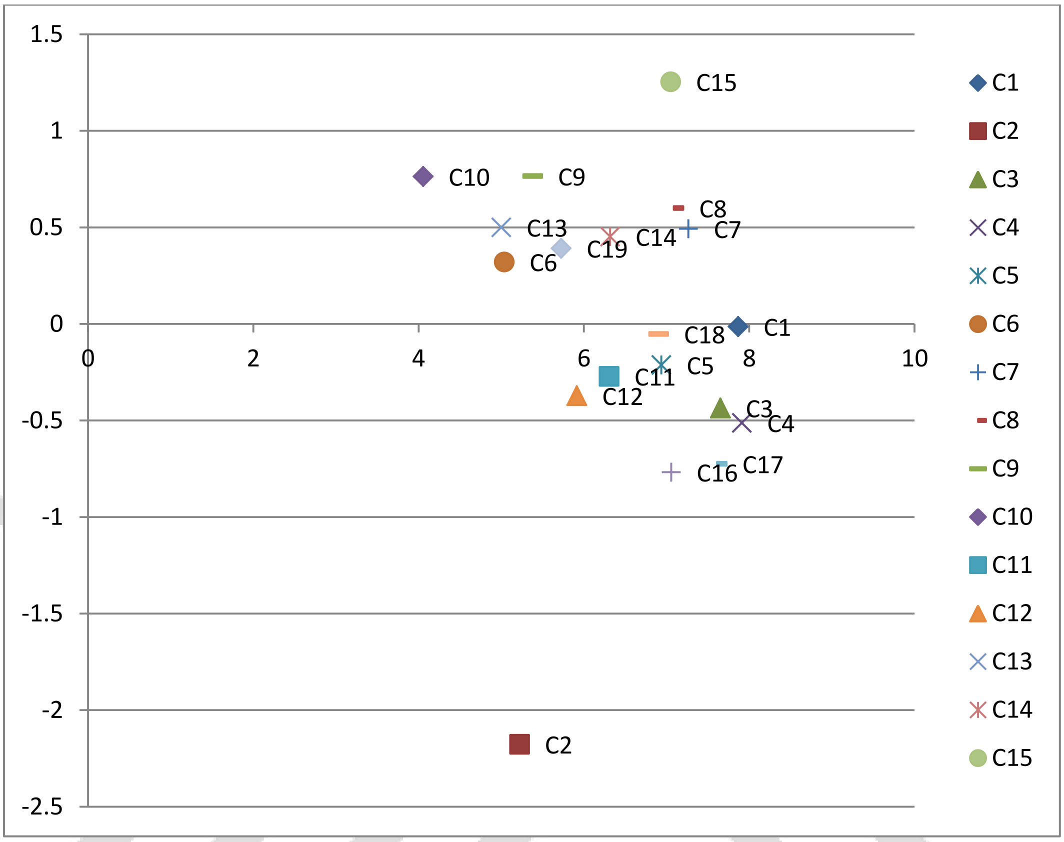


Figure 8: The Cause Effect Diagram

According to this result;

1) Robustness (C6), Volume Flexibility (C7), Routing Flexibility (C8), Topography and Topology (C9), Community Environment (C10), Property-related Security (C13), Maintenance (C14), Sustainability (C15), and Other Characteristics (C19) belong to the Cause Group.

2) Non-inventory Cost (C1), Inventory Cost (C2), Space Relationship (C3), Material Flow (C4), Non-material Flow (C5), Human-related Safety (C11), Worker-related Comfort (C12), Time in Production (C16), Time in Non-Production (C17), and Production Characteristics (C18) belong to the effect group.

The comparison can be made between the results of fuzzy TISM and fuzzy DEMATEL techniques. The group which denotes strong driving power in fuzzy TISM corresponds to the cause group in fuzzy DEMATEL; in other words, Linkage (III) and Independent (IV) groups correspond to the Cause group. The group which denotes strong dependence in fuzzy TISM corresponds to the effect group in fuzzy DEMATEL; in other words, Dependent (II) and Linkage (III) groups correspond to the Effect Group. As can be seen, Linkage employs as both cause and effect group, because it denotes both strong driving power and strong dependence.

The results of the fuzzy TISM and fuzzy DEMATEL seem consistent. Table 12 shows the details about the comparison.

Table 12: The Comparison of Fuzzy TISM and Fuzzy DEMATEL Results

Fuzzy TISM				Fuzzy DEMATEL	
I - Autonomous	II - Dependent	III - Linkage	IV - Independent	Cause Group	Effect Group
C6, C9, C10, C12, C13, C19	C2, C3, C11, C16	C1, C4, C5, C17, C18	C7, C8, C14, C15	C6, C7, C8,C9, C10, C13, C14, C15, C19	C1, C2, C3, C4, C5, C11, C12, C16, C17, C18

4.4. FUZZY ANP

Pairwise comparisons were made with five experts; the general manager, the operations manager, the vice operations manager, the member of the executive board, and the craft supervisor. Each expert made the pairwise comparisons using linguistic variables as equally important (E), moderately more important (MM), strongly more important (SM), very strongly more important (VSM), and extremely more important (EM). Tables 13-31 show the pairwise comparison matrix of one of the experts with respect to all sub-criteria.

Tables 67-142 in Appendix show the pairwise comparison matrices of Experts 2, 3, 4, and 5 with respect to all sub-criteria, respectively.

Tables 32-34 show the unweighted supermatrix, weighted supermatrix, and the limit matrix, respectively. The unweighted supermatrix was constructed using the geometric mean. Weighted supermatrix was obtained by multiplying the unweighted supermatrix with the total relation matrix, in other words, inner-dependence matrix, of fuzzy DEMATEL. The limit supermatrix is the limiting power of weighted supermatrix.

Table 13: Pairwise Comparison of Expert 1 with respect to Non-Inventory Cost

Non-Inventory Cost	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	SM	E	SM	VSM	MM	MM	EM	VSM	SM	SM	SM	SM	MM	MM	MM	SM	EM
Inventory Cost		E	MM	E	MM	SM	E	E	SM	VSM	MM	MM	MM	E	E	E	E	MM	VSM
Space Relationship			E	(MM)	E	MM	(MM)	(MM)	SM	EM	E	E	E	E	(MM)	(MM)	(MM)	E	SM
Material Flow				E	MM	SM	E	E	SM	SM	MM	MM	MM	MM	MM	E	E	MM	MM
Non-Material Flow					E	MM	(SM)	(MM)	MM	MM	E	E	E	(MM)	(MM)	(MM)	E	E	MM
Robustness						E	(VSM)	(SM)	MM	E	(MM)	(MM)	(MM)	(SM)	(SM)	(SM)	(MM)	(MM)	E
Volume Flexibility							E	MM	SM	MM	MM	MM	E	MM	MM	E	E	MM	SM
Routing Flexibility								E	SM	MM	MM	MM	MM	MM	E	E	MM	E	MM
Topography and Topology									E	(MM)	(SM)	(SM)	(SM)	(MM)	(SM)	(SM)	(MM)	(MM)	E
Community Environment										E	(SM)	(MM)	(MM)	(MM)	(VSM)	(MM)	(MM)	E	E
Human-related Safety											E	E	E	E	E	(MM)	E	E	MM
Worker-related Comfort												E	E	E	(MM)	E	(MM)	E	MM
Property-related Security													E	E	(MM)	E	E	E	SM
Maintenance														E	(MM)	(MM)	(MM)	(MM)	E
Sustainability															E	E	E	E	MM
Time in Production																E	E	E	SM
Time in non-Production																	E	E	SM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 14: Pairwise Comparison of Expert 1 with respect to Inventory Cost

Inventory Cost	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	MM	MM	MM	SM	MM	MM	VSM	SM	MM	MM	MM	MM	E	MM	MM	MM	VSM
Inventory Cost		E	MM	MM	MM	MM	MM	MM	SM	MM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Space Relationship			E	(SM)	(MM)	E	(MM)	(MM)	MM	SM	E	E	E	E	(MM)	(MM)	(MM)	E	SM
Material Flow				E	MM	MM	E	E	MM	SM	E	E	E	E	E	E	E	E	MM
Non-Material Flow					E	(MM)	(SM)	(MM)	MM	MM	E	E	E	(MM)	(MM)	(MM)	E	MM	SM
Robustness						E	(MM)	(MM)	SM	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	MM
Volume Flexibility							E	E	SM	SM	MM	MM	E	MM	E	(MM)	E	E	SM
Routing Flexibility								E	MM	MM	E	E	E	MM	E	E	E	E	MM
Topography and Topology									E	E	(MM)	(MM)	(MM)	(MM)	(VSM)	(SM)	(MM)	(MM)	MM
Community Environment										E	(MM)	(MM)	(MM)	(SM)	(SM)	(MM)	(MM)	E	MM
Human-related Safety											E	E	E	(MM)	(MM)	(MM)	(MM)	E	SM
Worker-related Comfort												E	MM	E	(MM)	(MM)	(MM)	E	SM
Property-related Security													E	(MM)	(MM)	E	E	MM	SM
Maintenance														E	(SM)	E	E	E	MM
Sustainability															E	E	MM	MM	VSM
Time in Production																E	E	MM	SM
Time in non-Production																	E	(MM)	SM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 15: Pairwise Comparison of Expert 1 with respect to Space Relationship

Space Relationship	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	(MM)	MM	MM	SM	MM	MM	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Inventory Cost		E	(MM)	MM	MM	MM	E	E	MM	SM	MM	MM	MM	MM	E	E	E	MM	SM
Space Relationship			E	MM	MM	SM	MM	MM	VSM	EM	MM	MM	MM	SM	MM	MM	MM	SM	VSM
Material Flow				E	MM	MM	E	MM	MM	SM	E	E	E	MM	E	MM	MM	SM	SM
Non-Material Flow					E	E	(MM)	E	MM	SM	MM	MM	MM	E	(MM)	(MM)	E	MM	MM
Robustness						E	(MM)	(MM)	MM	MM	E	E	E	(MM)	(SM)	(MM)	E	E	MM
Volume Flexibility							E	MM	SM	SM	MM	MM	E	MM	E	MM	E	SM	VSM
Routing Flexibility								E	MM	MM	E	E	E	MM	(MM)	(MM)	E	MM	SM
Topography and Topology									E	E	(MM)	(SM)	(MM)	(SM)	(VSM)	(MM)	(MM)	E	MM
Community Environment										E	(MM)	(SM)	(SM)	E	(SM)	(MM)	(SM)	(MM)	MM
Human-related Safety											E	MM	E	E	(MM)	(MM)	E	E	MM
Worker-related Comfort												E	SM	MM	MM	E	E	MM	VSM
Property-related Security													E	(MM)	E	E	MM	MM	SM
Maintenance														E	(MM)	MM	MM	E	SM
Sustainability															E	SM	SM	MM	VSM
Time in Production																E	MM	MM	SM
Time in non-Production																	E	(MM)	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 16: Pairwise Comparison of Expert 1 with respect to Material Flow

Material Flow	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	(SM)	MM	SM	MM	MM	VSM	SM	MM	MM	MM	MM	E	E	E	MM	SM
Inventory Cost		E	MM	(SM)	E	MM	E	MM	SM	SM	E	MM	MM	E	E	MM	E	MM	VSM
Space Relationship			E	(VSM)	(MM)	E	(MM)	(MM)	MM	SM	MM	MM	E	E	(MM)	E	E	MM	SM
Material Flow				E	SM	SM	MM	MM	SM	SM	MM	MM	SM	MM	MM	SM	SM	SM	VSM
Non-Material Flow					E	E	(MM)	(MM)	MM	MM	E	MM	E	E	(SM)	E	E	MM	MM
Robustness						E	(SM)	(MM)	MM	MM	E	(MM)	(MM)	(MM)	(SM)	(MM)	E	E	MM
Volume Flexibility							E	E	MM	SM	SM	MM	SM	MM	E	E	MM	MM	SM
Routing Flexibility								E	MM	MM	E	MM	MM	MM	(MM)	E	E	E	MM
Topography and Topology									E	E	(MM)	(SM)	(MM)	(MM)	(SM)	E	E	E	MM
Community Environment										E	E	E	E	E	(MM)	E	E	MM	MM
Human-related Safety											E	E	E	(MM)	(SM)	E	E	E	SM
Worker-related Comfort												E	(MM)	(MM)	(SM)	E	(MM)	(MM)	E
Property-related Security													E	(MM)	(SM)	(MM)	(MM)	E	MM
Maintenance														E	(MM)	E	E	E	MM
Sustainability															E	MM	MM	MM	SM
Time in Production																E	E	MM	SM
Time in non-Production																	E	E	SM
Production Characteristics																		E	SM
Other Characteristics																			E

Table 17: Pairwise Comparison of Expert 1 with respect to Non-Material Flow

Non-Material Flow	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	MM	(SM)	MM	E	E	SM	MM	MM	MM	SM	MM	E	MM	E	E	MM
Inventory Cost		E	(MM)	E	(SM)	MM	E	E	MM	MM	MM	MM	SM	MM	E	MM	E	E	SM
Space Relationship			E	E	(MM)	MM	E	E	SM	SM	MM	MM	MM	MM	E	E	E	MM	SM
Material Flow				E	(MM)	MM	(MM)	(MM)	MM	MM	MM	E	MM	E	E	(MM)	(MM)	E	MM
Non-Material Flow					E	SM	MM	MM	VSM	SM	MM	MM	SM	SM	MM	MM	MM	SM	SM
Robustness						E	(MM)	(MM)	E	E	(MM)	(SM)	(SM)	(MM)	(SM)	(MM)	(MM)	(MM)	(MM)
Volume Flexibility							E	MM	SM	SM	MM	MM	MM	MM	E	MM	MM	MM	SM
Routing Flexibility								E	MM	MM	E	E	MM	E	(MM)	E	MM	E	MM
Topography and Topology									E	E	(MM)	(MM)	(MM)	E	(MM)	E	E	E	MM
Community Environment										E	(MM)	E	E	E	(SM)	(MM)	(MM)	(MM)	(MM)
Human-related Safety											E	(MM)	E	E	(MM)	(MM)	(MM)	E	MM
Worker-related Comfort												E	MM	MM	(MM)	E	E	MM	MM
Property-related Security													E	E	(SM)	E	E	MM	MM
Maintenance														E	(MM)	(MM)	(MM)	E	E
Sustainability															E	MM	MM	MM	SM
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 18: Pairwise Comparison of Expert 1 with respect to Robustness

Robustness	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	SM	MM	SM	E	MM	SM	VSM	SM	MM	SM	SM	SM	E	MM	MM	MM	SM
Inventory Cost		E	MM	E	MM	(MM)	E	MM	SM	SM	MM	SM	MM	MM	E	MM	MM	MM	VSM
Space Relationship			E	(MM)	E	(MM)	(MM)	E	MM	SM	MM	SM	MM	MM	(MM)	E	(MM)	MM	SM
Material Flow				E	MM	E	E	MM	SM	SM	MM	SM	MM	E	E	E	E	MM	SM
Non-Material Flow					E	(MM)	(MM)	E	MM	MM	E	MM	E	E	(SM)	(MM)	E	E	MM
Robustness						E	E	MM	SM	SM	MM	SM	MM	MM	MM	MM	MM	MM	SM
Volume Flexibility							E	MM	SM	SM	MM	SM	E	MM	E	MM	MM	SM	SM
Routing Flexibility								E	SM	MM	MM	SM	E	MM	E	MM	MM	E	MM
Topography and Topology									E	E	(MM)	(MM)	(MM)	(MM)	(SM)	(MM)	E	E	E
Community Environment										E	(MM)	E	E	E	(SM)	E	E	MM	MM
Human-related Safety											E	E	(MM)	E	(SM)	E	E	MM	MM
Worker-related Comfort												E	(MM)	E	(SM)	(MM)	(MM)	E	MM
Property-related Security													E	E	(SM)	E	E	E	E
Maintenance														E	(MM)	E	E	E	E
Sustainability															E	MM	MM	SM	SM
Time in Production																E	E	MM	MM
Time in non-Production																	E	MM	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 19: Pairwise Comparison of Expert 1 with respect to Volume Flexibility

Volume Flexibility	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	SM	SM	(MM)	MM	SM	SM	MM	MM	MM	MM	E	MM	MM	MM	VSM
Inventory Cost		E	E	(MM)	MM	MM	(MM)	MM	SM	SM	MM	SM	MM	E	(MM)	E	E	MM	SM
Space Relationship			E	E	MM	SM	(SM)	E	SM	SM	MM	MM	MM	MM	(MM)	E	E	E	MM
Material Flow				E	MM	SM	(MM)	E	SM	SM	MM	MM	SM	MM	E	MM	MM	MM	SM
Non-Material Flow					E	MM	(SM)	E	MM	MM	E	MM	E	E	(SM)	(MM)	E	MM	SM
Robustness						E	(SM)	(MM)	MM	MM	(MM)	E	E	(MM)	(SM)	(MM)	(MM)	(MM)	E
Volume Flexibility							E	MM	VSM	VSM	SM	SM	SM	SM	MM	MM	MM	MM	VSM
Routing Flexibility								E	MM	MM	E	E	E	E	(MM)	E	MM	E	MM
Topography and Topology									E	E	(MM)	(MM)	E	(MM)	(SM)	(MM)	(MM)	(MM)	E
Community Environment										E	(MM)	(MM)	E	E	(SM)	(MM)	(MM)	(MM)	E
Human-related Safety											E	MM	E	E	(SM)	E	E	E	E
Worker-related Comfort												E	E	E	(MM)	(MM)	(MM)	E	E
Property-related Security													E	(MM)	(SM)	E	E	E	MM
Maintenance														E	(MM)	E	E	E	E
Sustainability															E	MM	MM	MM	MM
Time in Production																E	E	E	E
Time in non-Production																	E	MM	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 20: Pairwise Comparison of Expert 1 with respect to Routing Flexibility

Routing Flexibility	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	MM	E	MM	MM	E	(MM)	SM	SM	MM	MM	MM	MM	E	E	E	MM	MM
Inventory Cost		E	E	(MM)	E	MM	(MM)	(SM)	MM	SM	MM	E	MM	E	(MM)	E	E	E	MM
Space Relationship			E	E	E	MM	E	(SM)	SM	SM	MM	MM	MM	E	(MM)	E	E	MM	MM
Material Flow				E	MM	MM	E	(MM)	MM	MM	MM	MM	MM	MM	E	MM	MM	MM	MM
Non-Material Flow					E	MM	(MM)	(SM)	MM	SM	MM	MM	SM	E	(MM)	E	E	MM	MM
Robustness						E	(MM)	(VSM)	E	E	E	E	E	(MM)	(SM)	(MM)	E	E	MM
Volume Flexibility							E	(MM)	SM	SM	MM	MM	MM	MM	E	MM	MM	MM	MM
Routing Flexibility								E	VSM	VSM	SM	SM	SM	MM	MM	MM	MM	MM	SM
Topography and Topology									E	E	E	E	E	E	(MM)	E	E	E	MM
Community Environment										E	E	E	E	E	(MM)	E	E	E	E
Human-related Safety											E	E	E	(MM)	(SM)	(MM)	(MM)	(MM)	E
Worker-related Comfort												E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Property-related Security													E	E	(SM)	(MM)	(MM)	(MM)	E
Maintenance														E	(MM)	E	E	E	MM
Sustainability															E	SM	SM	SM	SM
Time in Production																E	MM	E	MM
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 21: Pairwise Comparison of Expert 1 with respect to Topography and Topology

Topography and Topology	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	E	MM	E	E	(MM)	SM	MM	MM	MM	MM	E	E	E	MM	E
Inventory Cost		E	E	E	E	MM	E	E	(MM)	MM	MM	MM	MM	E	E	E	E	E	E
Space Relationship			E	E	E	MM	E	E	(MM)	SM	MM	MM	MM	MM	(MM)	E	E	MM	E
Material Flow				E	E	MM	E	E	(MM)	SM	MM	MM	SM	MM	E	E	E	E	E
Non-Material Flow					E	MM	(MM)	E	(MM)	MM	E	MM	MM	E	(MM)	E	E	E	E
Robustness						E	(MM)	E	(SM)	MM	E	E	E	(MM)	(MM)	E	E	E	(MM)
Volume Flexibility							E	MM	(MM)	SM	MM	MM	MM	MM	E	E	MM	MM	E
Routing Flexibility								E	(MM)	MM	MM	E	MM	E	(MM)	E	E	E	E
Topography and Topology									E	SM	SM	SM	MM	SM	MM	SM	SM	SM	MM
Community Environment										E	(MM)	E	E	E	(MM)	E	E	E	(MM)
Human-related Safety											E	E	E	E	(MM)	E	E	E	(MM)
Worker-related Comfort												E	E	E	(MM)	E	E	E	(MM)
Property-related Security													E	E	(MM)	E	E	E	(MM)
Maintenance														E	(MM)	E	E	E	(MM)
Sustainability															E	MM	MM	MM	E
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 22: Pairwise Comparison of Expert 1 with respect to Community Environment

Community Environment	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	E	MM	E	E	MM	(MM)	MM	MM	MM	MM	E	MM	MM	MM	E
Inventory Cost		E	E	E	E	MM	E	E	MM	(MM)	MM	MM	MM	MM	E	E	E	MM	E
Space Relationship			E	(MM)	E	MM	(MM)	E	MM	(MM)	MM	MM	MM	MM	(MM)	E	E	E	E
Material Flow				E	MM	MM	E	E	SM	(MM)	MM	MM	MM	MM	E	E	E	MM	E
Non-Material Flow					E	MM	(MM)	E	MM	(MM)	MM	MM	MM	E	(MM)	E	E	E	E
Robustness						E	(MM)	(MM)	MM	(SM)	E	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)
Volume Flexibility							E	MM	MM	(MM)	MM	MM	MM	MM	E	MM	MM	MM	E
Routing Flexibility								E	MM	(MM)	E	E	E	E	(MM)	E	E	E	(MM)
Topography and Topology									E	(MM)	E	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)
Community Environment										E	SM	MM	MM	MM	MM	MM	MM	MM	MM
Human-related Safety											E	E	E	E	(MM)	E	E	E	(MM)
Worker-related Comfort												E	E	E	(MM)	E	E	E	(MM)
Property-related Security													E	E	(MM)	E	E	E	(MM)
Maintenance														E	(MM)	E	E	E	(MM)
Sustainability															E	MM	MM	MM	E
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 23: Pairwise Comparison of Expert 1 with respect to Human-related Safety

Human-related Safety	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	E	SM	MM	SM	SM	SM	(MM)	SM	SM	SM	MM	MM	MM	MM	SM
Inventory Cost		E	E	MM	(MM)	MM	E	MM	MM	MM	(MM)	MM	MM	MM	E	E	E	MM	MM
Space Relationship			E	E	(MM)	MM	E	E	MM	MM	(MM)	MM	MM	MM	E	E	E	E	MM
Material Flow				E	(MM)	MM	E	E	MM	MM	(MM)	MM	MM	MM	E	E	E	E	MM
Non-Material Flow					E	MM	MM	MM	SM	SM	(MM)	MM	MM	MM	E	MM	MM	MM	SM
Robustness						E	(MM)	(MM)	MM	MM	(SM)	E	E	E	(MM)	(MM)	(MM)	(MM)	E
Volume Flexibility							E	MM	SM	SM	(MM)	MM	MM	MM	E	E	MM	MM	MM
Routing Flexibility								E	MM	MM	(MM)	MM	MM	MM	E	MM	MM	MM	MM
Topography and Topology									E	E	(SM)	E	E	E	(MM)	E	E	E	E
Community Environment										E	(SM)	E	E	E	(MM)	E	E	E	E
Human-related Safety											E	SM	SM	SM	MM	MM	MM	MM	SM
Worker-related Comfort												E	E	E	(MM)	(MM)	(MM)	(MM)	E
Property-related Security													E	E	(MM)	(MM)	(MM)	(MM)	MM
Maintenance														E	(MM)	E	E	E	MM
Sustainability															E	MM	MM	MM	SM
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 24: Pairwise Comparison of Expert 1 with respect Worker-related Comfort

Worker-related Comfort	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	(MM)	SM	MM	MM	SM	SM	MM	(SM)	MM	MM	MM	MM	MM	SM	SM
Inventory Cost		E	E	E	(MM)	MM	E	MM	SM	SM	MM	(SM)	MM	MM	E	MM	MM	MM	SM
Space Relationship			E	E	(MM)	MM	(MM)	MM	SM	SM	MM	(SM)	MM	MM	E	MM	MM	MM	SM
Material Flow				E	(MM)	SM	MM	MM	SM	SM	MM	(SM)	MM	MM	E	MM	MM	MM	MM
Non-Material Flow					E	MM	MM	MM	SM	SM	MM	(MM)	MM	MM	MM	MM	MM	MM	SM
Robustness						E	(MM)	(MM)	MM	E	E	(SM)	MM	E	(MM)	E	E	E	E
Volume Flexibility							E	MM	SM	SM	MM	(MM)	SM	MM	E	MM	MM	MM	SM
Routing Flexibility								E	SM	MM	MM	(SM)	MM	MM	(MM)	MM	MM	MM	SM
Topography and Topology									E	E	E	(SM)	MM	(MM)	(SM)	(MM)	(MM)	(MM)	E
Community Environment										E	E	(SM)	MM	MM	(MM)	E	E	E	MM
Human-related Safety											E	(MM)	MM	E	(MM)	E	E	E	MM
Worker-related Comfort												E	VSM	SM	MM	SM	MM	SM	SM
Property-related Security													E	(MM)	(SM)	E	E	E	MM
Maintenance														E	(MM)	(MM)	(MM)	(MM)	E
Sustainability															E	MM	MM	MM	MM
Time in Production																E	E	E	E
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 25: Pairwise Comparison of Expert 1 with respect Property-related Security

Property-related Security	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	SM	MM	MM	SM	SM	MM	SM	SM	SM	SM	SM	(MM)	MM	MM	MM	MM	SM	SM
Inventory Cost		E	(MM)	E	MM	MM	E	MM	MM	MM	MM	MM	(MM)	MM	E	E	E	MM	SM
Space Relationship			E	MM	MM	MM	MM	MM	SM	SM	MM	MM	(MM)	MM	E	E	E	E	MM
Material Flow				E	MM	MM	E	MM	SM	SM	MM	MM	(MM)	MM	MM	E	E	MM	MM
Non-Material Flow					E	MM	E	MM	MM	SM	MM	MM	(MM)	E	E	E	E	E	MM
Robustness						E	(MM)	E	MM	MM	E	E	(SM)	E	(MM)	(MM)	(MM)	(MM)	E
Volume Flexibility							E	MM	SM	SM	MM	MM	(MM)	MM	MM	MM	MM	MM	SM
Routing Flexibility								E	SM	MM	MM	MM	(MM)	MM	E	E	MM	E	MM
Topography and Topology									E	MM	E	E	(SM)	E	(MM)	E	E	E	MM
Community Environment										E	E	E	(SM)	E	(MM)	E	E	E	MM
Human-related Safety											E	E	(SM)	E	(MM)	E	E	E	MM
Worker-related Comfort												E	(SM)	E	(MM)	E	E	E	E
Property-related Security													E	SM	MM	SM	SM	SM	VSM
Maintenance														E	(MM)	(MM)	(MM)	(MM)	E
Sustainability															E	E	E	MM	MM
Time in Production																E	MM	MM	SM
Time in non-Production																	E	MM	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 26: Pairwise Comparison of Expert 1 with respect Maintenance

Maintenance	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	SM	SM	SM	SM	SM	SM	SM	SM	SM	MM	(MM)	MM	MM	E	MM	SM
Inventory Cost		E	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	E	(MM)	E	E	E	E	MM
Space Relationship			E	E	MM	MM	MM	MM	SM	MM	MM	MM	E	(MM)	MM	MM	E	MM	SM
Material Flow				E	E	(MM)	E	E	MM	MM	MM	MM	MM	(MM)	E	E	E	MM	MM
Non-Material Flow					E	(MM)	E	E	MM	MM	MM	MM	MM	(MM)	E	E	E	MM	MM
Robustness						E	SM	MM	MM	MM	MM	MM	MM	(MM)	E	E	E	E	MM
Volume Flexibility							E	E	E	E	E	E	E	(SM)	E	E	E	E	MM
Routing Flexibility								E	E	E	E	E	E	(SM)	E	E	E	E	MM
Topography and Topology									E	MM	E	E	E	(SM)	E	E	E	E	E
Community Environment										E	E	E	E	(SM)	E	E	E	E	MM
Human-related Safety											E	MM	MM	(SM)	MM	E	E	E	MM
Worker-related Comfort												E	(MM)	(SM)	MM	MM	MM	MM	MM
Property-related Security													E	(MM)	MM	MM	MM	MM	SM
Maintenance														E	SM	SM	SM	SM	VSM
Sustainability															E	E	E	E	E
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 27: Pairwise Comparison of Expert 1 with respect Sustainability

Sustainability	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	SM	SM	SM	SM	SM	SM	VSM	VSM	SM	SM	SM	SM	(MM)	MM	MM	MM	SM
Inventory Cost		E	MM	MM	MM	MM	MM	MM	SM	SM	MM	MM	MM	MM	(MM)	E	E	E	MM
Space Relationship			E	E	E	E	E	E	MM	MM	MM	E	MM	E	(SM)	E	E	E	MM
Material Flow				E	E	E	E	E	MM	MM	MM	MM	MM	E	(MM)	E	E	MM	MM
Non-Material Flow					E	E	E	E	MM	MM	E	E	E	(MM)	(SM)	E	E	E	MM
Robustness						E	E	E	MM	MM	E	E	E	E	(MM)	E	E	E	MM
Volume Flexibility							E	E	E	E	E	E	E	E	(SM)	E	E	E	E
Routing Flexibility								E	E	E	E	E	E	E	(SM)	E	E	E	MM
Topography and Topology									E	E	E	E	E	E	(SM)	E	E	E	E
Community Environment										E	E	E	E	E	(VSM)	E	E	E	E
Human-related Safety											E	E	E	E	(SM)	(MM)	E	E	MM
Worker-related Comfort												E	E	E	(SM)	E	(MM)	E	E
Property-related Security													E	E	(SM)	E	E	E	MM
Maintenance														E	(MM)	E	E	E	E
Sustainability															E	SM	SM	SM	SM
Time in Production																E	MM	E	E
Time in non-Production																	E	MM	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 28: Pairwise Comparison of Expert 1 with respect Time in Production

Time in Production	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	(MM)	(MM)	E	(MM)	(MM)	E	E	E	(MM)	E	(MM)	E	(SM)	(MM)	(MM)	(MM)
Inventory Cost		E	E	(MM)	(MM)	E	(MM)	(MM)	E	E	E	(MM)	E	(MM)	E	(SM)	(MM)	(MM)	(MM)
Space Relationship			E	E	E	E	E	E	E	E	E	E	E	E	E	(MM)	E	E	E
Material Flow				E	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	(MM)	E	E	E
Non-Material Flow					E	MM	E	E	MM	MM	MM	MM	MM	MM	MM	(MM)	E	E	E
Robustness						E	E	E	E	E	E	E	E	E	E	(SM)	(MM)	(MM)	(MM)
Volume Flexibility							E	E	E	E	E	E	E	E	E	(SM)	(MM)	(MM)	(MM)
Routing Flexibility								E	MM	E	E	E	E	E	E	(SM)	(MM)	(MM)	(MM)
Topography and Topology									E	E	E	E	E	E	E	(SM)	(MM)	(MM)	(MM)
Community Environment										E	E	E	E	E	E	(SM)	(MM)	(MM)	(MM)
Human-related Safety											E	E	E	E	E	(SM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	E	E	E	(SM)	(MM)	(MM)	(MM)
Property-related Security													E	E	E	(SM)	(MM)	(MM)	(MM)
Maintenance														E	E	(SM)	(MM)	(MM)	(MM)
Sustainability															E	(SM)	(MM)	(MM)	(MM)
Time in Production																E	MM	MM	MM
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 29: Pairwise Comparison of Expert 1 with respect Time in Non-Production

Time in non-Production	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	(MM)	(MM)	E	(MM)	(MM)	E	E	E	(MM)	E	(MM)	E	(MM)	(SM)	(MM)	(MM)
Inventory Cost		E	E	(MM)	(MM)	E	(MM)	(MM)	E	E	E	(MM)	E	(MM)	E	(MM)	(SM)	(MM)	(MM)
Space Relationship			E	E	E	E	E	E	E	E	E	E	E	E	E	(MM)	(SM)	E	E
Material Flow				E	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	(MM)	(SM)	E	E
Non-Material Flow					E	MM	E	E	MM	MM	MM	MM	MM	MM	MM	(MM)	(SM)	E	E
Robustness						E	E	E	E	E	E	E	E	E	E	(MM)	(SM)	(MM)	(MM)
Volume Flexibility							E	E	E	E	E	E	E	E	E	(MM)	(SM)	(MM)	(MM)
Routing Flexibility								E	MM	E	E	E	E	E	E	(MM)	(SM)	(MM)	(MM)
Topography and Topology									E	E	E	E	E	E	E	(MM)	(SM)	(MM)	(MM)
Community Environment										E	E	E	E	E	E	(MM)	(SM)	(MM)	(MM)
Human-related Safety											E	E	E	E	E	(MM)	(SM)	(MM)	(MM)
Worker-related Comfort												E	E	E	E	(MM)	(SM)	(MM)	(MM)
Property-related Security													E	E	E	(MM)	(SM)	(MM)	(MM)
Maintenance														E	E	(MM)	(SM)	(MM)	(MM)
Sustainability															E	(MM)	(SM)	(MM)	(MM)
Time in Production																E	(MM)	E	E
Time in non-Production																	E	MM	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 30: Pairwise Comparison of Expert 1 with respect Production Characteristics

Production Characteristics	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	(MM)	MM	MM	MM	SM	E	E	SM	SM	SM	SM	SM	MM	MM	E	E	(MM)	MM
Inventory Cost		E	SM	SM	SM	VSM	SM	SM	VSM	VSM	VSM	VSM	VSM	SM	MM	E	E	(MM)	MM
Space Relationship			E	E	E	MM	E	E	SM	SM	MM	MM	MM	MM	MM	E	E	(MM)	MM
Material Flow				E	E	MM	E	E	SM	SM	MM	MM	MM	MM	MM	E	E	(MM)	E
Non-Material Flow					E	MM	E	E	MM	MM	MM	MM	MM	MM	MM	E	E	(MM)	E
Robustness						E	(MM)	(MM)	E	E	E	E	E	E	E	(MM)	(MM)	(SM)	(MM)
Volume Flexibility							E	E	MM	MM	MM	MM	MM	MM	MM	E	E	(MM)	E
Routing Flexibility								E	MM	MM	MM	MM	MM	MM	MM	E	E	(MM)	E
Topography and Topology									E	E	E	E	E	E	E	(MM)	(MM)	(SM)	(MM)
Community Environment										E	E	E	E	E	(VSM)	(MM)	(MM)	(SM)	(MM)
Human-related Safety											E	E	E	E	E	(MM)	(MM)	(SM)	(MM)
Worker-related Comfort												E	E	E	E	(MM)	(MM)	(SM)	(MM)
Property-related Security													E	E	E	(MM)	(MM)	(SM)	(MM)
Maintenance														E	E	(MM)	(MM)	(SM)	(MM)
Sustainability															E	(MM)	(MM)	(SM)	(MM)
Time in Production																E	E	(MM)	E
Time in non-Production																	E	(MM)	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 31: Pairwise Comparison of Expert 1 with respect Other Characteristics

Other Characteristics	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	(MM)	(MM)	(MM)	E	(MM)	E	(MM)	(MM)	E	E	E	E	E	(MM)	(MM)	(MM)	(SM)
Inventory Cost		E	(MM)	(MM)	(MM)	E	(MM)	E	(MM)	(MM)	E	E	E	E	E	(MM)	(MM)	(MM)	(SM)
Space Relationship			E	E	E	MM	E	MM	E	E	MM	MM	MM	MM	MM	E	E	E	(MM)
Material Flow				E	E	MM	E	MM	E	E	MM	MM	MM	MM	MM	E	E	E	(MM)
Non-Material Flow					E	MM	E	MM	E	E	MM	MM	MM	MM	MM	E	E	E	(MM)
Robustness						E	(MM)	(MM)	(MM)	(MM)	E	E	E	E	E	(MM)	(MM)	(MM)	(SM)
Volume Flexibility							E	E	E	E	MM	MM	MM	MM	MM	E	E	E	(MM)
Routing Flexibility								E	(MM)	(MM)	E	E	E	E	E	(MM)	(MM)	(MM)	(SM)
Topography and Topology									E	E	MM	MM	MM	MM	MM	E	E	E	(MM)
Community Environment										E	MM	MM	MM	MM	MM	E	E	E	(MM)
Human-related Safety											E	E	E	E	E	(MM)	(MM)	(MM)	(SM)
Worker-related Comfort												E	E	E	E	(MM)	(MM)	(MM)	(SM)
Property-related Security													E	E	E	(MM)	(MM)	(MM)	(SM)
Maintenance														E	E	(MM)	(MM)	(MM)	(SM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 32: The Unweighted Supermatrix

UNWEIGHTED SUPERMATRIX	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	0.192	0.066	0.088	0.091	0.044	0.092	0.087	0.061	0.049	0.051	0.072	0.061	0.069	0.075	0.081	0.027	0.027	0.051	0.048
Inventory Cost	0.042	0.176	0.044	0.056	0.054	0.087	0.051	0.041	0.036	0.036	0.035	0.036	0.034	0.037	0.046	0.029	0.028	0.047	0.031
Space Relationship	0.036	0.038	0.188	0.043	0.063	0.035	0.055	0.048	0.038	0.040	0.033	0.037	0.041	0.060	0.039	0.027	0.027	0.033	0.033
Material Flow	0.052	0.044	0.053	0.199	0.029	0.041	0.063	0.061	0.037	0.041	0.035	0.037	0.040	0.045	0.035	0.064	0.062	0.042	0.043
Non-Material Flow	0.024	0.027	0.025	0.023	0.196	0.028	0.021	0.028	0.027	0.027	0.035	0.036	0.027	0.027	0.023	0.041	0.040	0.040	0.041
Robustness	0.021	0.023	0.022	0.022	0.024	0.168	0.021	0.026	0.025	0.025	0.026	0.027	0.027	0.028	0.027	0.025	0.025	0.022	0.022
Volume Flexibility	0.049	0.039	0.038	0.039	0.034	0.040	0.193	0.046	0.034	0.037	0.037	0.037	0.038	0.028	0.026	0.029	0.029	0.030	0.029
Routing Flexibility	0.035	0.027	0.024	0.025	0.033	0.029	0.027	0.174	0.026	0.026	0.027	0.026	0.029	0.024	0.023	0.029	0.029	0.028	0.023
Topography and Topology	0.021	0.022	0.020	0.021	0.026	0.024	0.020	0.027	0.197	0.027	0.026	0.025	0.028	0.025	0.024	0.024	0.024	0.021	0.024
Community Environment	0.021	0.022	0.020	0.021	0.025	0.025	0.020	0.027	0.027	0.184	0.026	0.026	0.028	0.025	0.024	0.024	0.024	0.020	0.023
Human-related Safety	0.025	0.026	0.024	0.025	0.030	0.026	0.024	0.027	0.030	0.029	0.196	0.029	0.031	0.026	0.025	0.026	0.025	0.022	0.023
Worker-related Comfort	0.024	0.027	0.027	0.023	0.031	0.025	0.023	0.027	0.028	0.028	0.029	0.212	0.030	0.029	0.027	0.030	0.029	0.023	0.023
Property-related Security	0.023	0.024	0.022	0.023	0.026	0.024	0.022	0.027	0.027	0.027	0.026	0.025	0.198	0.034	0.028	0.024	0.024	0.020	0.020
Maintenance	0.025	0.033	0.027	0.028	0.027	0.026	0.025	0.030	0.027	0.026	0.024	0.024	0.027	0.184	0.029	0.028	0.028	0.022	0.021
Sustainability	0.025	0.027	0.024	0.024	0.025	0.026	0.024	0.029	0.026	0.025	0.025	0.024	0.026	0.024	0.186	0.024	0.024	0.019	0.017
Time in Production	0.047	0.049	0.041	0.036	0.030	0.035	0.031	0.035	0.030	0.029	0.031	0.028	0.032	0.028	0.031	0.220	0.075	0.039	0.035
Time in non-Production	0.041	0.041	0.033	0.034	0.029	0.035	0.031	0.034	0.029	0.029	0.031	0.028	0.031	0.033	0.036	0.073	0.215	0.039	0.034
Production Characteristics	0.033	0.036	0.025	0.026	0.026	0.028	0.026	0.029	0.030	0.031	0.029	0.027	0.029	0.027	0.032	0.032	0.032	0.176	0.044
Other Characteristics	0.021	0.022	0.019	0.020	0.024	0.024	0.021	0.029	0.058	0.065	0.031	0.029	0.030	0.025	0.031	0.032	0.030	0.038	0.180

Table 33: The Weighted Supermatrix

WEIGHTED SUPERMATRIX	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	0.0383568	0.0158875	0.0227781	0.0245341	0.0103821	0.0119457	0.0177683	0.0115651	0.0077862	0.0063044	0.0155605	0.0126265	0.0107990	0.0152347	0.0159093	0.0068473	0.0072329	0.0117158	0.0084572
Inventory Cost	0.0049713	0.0133904	0.0048137	0.0054901	0.0038563	0.0048821	0.0057521	0.0027153	0.0017004	0.0012315	0.0022770	0.0026400	0.0027644	0.0037358	0.0029851	0.0026792	0.0028607	0.0042711	0.0017253
Space Relationship	0.0079857	0.0089772	0.0352540	0.0108982	0.0137005	0.0048823	0.0114871	0.0096960	0.0054629	0.0046509	0.0060167	0.0069149	0.0051350	0.0105848	0.0060050	0.0066320	0.0067415	0.0066236	0.0052960
Material Flow	0.0128832	0.0088551	0.0133554	0.0402036	0.0064594	0.0067147	0.0138557	0.0131231	0.0056971	0.0040959	0.0067206	0.0059921	0.0051902	0.0082931	0.0067332	0.0148774	0.0159748	0.0093602	0.0064453
Non-Material Flow	0.0056102	0.0052411	0.0059693	0.0054732	0.0304898	0.0038097	0.0037141	0.0054468	0.0037886	0.0025730	0.0064811	0.0062565	0.0032404	0.0042495	0.0038783	0.0085994	0.0096479	0.0078411	0.0048166
Robustness	0.0031953	0.0045218	0.0037313	0.0042154	0.0033127	0.0139398	0.0037353	0.0038049	0.0021067	0.0013716	0.0035830	0.0030363	0.0022011	0.0043571	0.0029458	0.0048437	0.0050713	0.0039298	0.0025871
Volume Flexibility	0.0124960	0.0091960	0.0099104	0.0107249	0.0077330	0.0063610	0.0329218	0.0095242	0.0048951	0.0031020	0.0074287	0.0069241	0.0058112	0.0052373	0.0049959	0.0073571	0.0078674	0.0070378	0.0049302
Routing Flexibility	0.0085542	0.0058459	0.0063720	0.0068915	0.0075259	0.0047007	0.0062877	0.0282282	0.0038965	0.0021272	0.0054037	0.0049282	0.0038518	0.0043534	0.0045130	0.0074019	0.0078237	0.0064820	0.0042066
Topography and Topology	0.0044438	0.0037337	0.0041566	0.0046464	0.0051517	0.0027510	0.0033545	0.0043451	0.0183338	0.0023552	0.0046313	0.0043588	0.0033855	0.0035346	0.0035950	0.0044792	0.0053034	0.0031839	0.0026597
Community Environment	0.0028840	0.0027950	0.0034039	0.0033443	0.0036797	0.0021490	0.0023323	0.0033958	0.0028338	0.0100693	0.0042166	0.0041554	0.0023991	0.0024099	0.0033878	0.0037066	0.0038154	0.0026316	0.0021207
Human-related Safety	0.0048634	0.0044528	0.0048723	0.0052817	0.0056767	0.0030513	0.0037067	0.0048574	0.0031033	0.0024301	0.0252409	0.0052466	0.0030504	0.0033209	0.0035458	0.0052127	0.0053909	0.0036456	0.0034273
Worker-related Comfort	0.0044356	0.0042871	0.0050279	0.0044803	0.0054741	0.0024937	0.0035965	0.0035842	0.0027945	0.0023914	0.0049915	0.0240848	0.0024817	0.0031074	0.0036257	0.0054567	0.0058710	0.0039431	0.0033307
Property-related Security	0.0044968	0.0042699	0.0041309	0.0047787	0.0045939	0.0029097	0.0033826	0.0046524	0.0037227	0.0019624	0.0033971	0.0031217	0.0160274	0.0041303	0.0032081	0.0039775	0.0043949	0.0027021	0.0019838
Maintenance	0.0055338	0.0072533	0.0053683	0.0057679	0.0044843	0.0039462	0.0047468	0.0053861	0.0031938	0.0024096	0.0046929	0.0044961	0.0037557	0.0236297	0.0052215	0.0062973	0.0063515	0.0044901	0.0032096
Sustainability	0.0065526	0.0068575	0.0060657	0.0068639	0.0062057	0.0041876	0.0054029	0.0063939	0.0045846	0.0036086	0.0056471	0.0054044	0.0046275	0.0046350	0.0287127	0.0062081	0.0065166	0.0044380	0.0031359
Time in Production	0.0090759	0.0106562	0.0088316	0.0082130	0.0051440	0.0040940	0.0060583	0.0063032	0.0027363	0.0019434	0.0055162	0.0049408	0.0029870	0.0041294	0.0039718	0.0349464	0.0164372	0.0073486	0.0058810
Time in non-Production	0.0098774	0.0085105	0.0077957	0.0080851	0.0060645	0.0044363	0.0059426	0.0065739	0.0031697	0.0022778	0.0059280	0.0050104	0.0045555	0.0057956	0.0058393	0.0161842	0.0397680	0.0069453	0.0058618
Production Characteristics	0.0074248	0.0080259	0.0056650	0.0062529	0.0053725	0.0034939	0.0049566	0.0054357	0.0037903	0.0029992	0.0052319	0.0047062	0.0036418	0.0051542	0.0049470	0.0074526	0.0067990	0.0271343	0.0069074
Other Characteristics	0.0039584	0.0041161	0.0041657	0.0042536	0.0043849	0.0025796	0.0030488	0.0037150	0.0072042	0.0057864	0.0053384	0.0049478	0.0037214	0.0039510	0.0052067	0.0061990	0.0062064	0.0068224	0.0190228

Table 34: The Limit Supermatrix

LIMIT SUPERMATRIX	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121
Inventory Cost	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
Space Relationship	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
Material Flow	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089
Non-Material Flow	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Robustness	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Volume Flexibility	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
Routing Flexibility	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
Topography and Topology	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
Community Environment	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026
Human-related Safety	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Worker-related Comfort	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
Property-related Security	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Maintenance	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
Sustainability	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
Time in Production	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
Time in non-Production	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Production Characteristics	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
Other Characteristics	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043

Table 35 shows the weights of the sub-criteria.

Table 35: The Sub-Criteria Weights

CRITERIA	WEIGHTS
Non-Inventory Cost	0.121
Inventory Cost	0.029
Space Relationship	0.072
Material Flow	0.089
Non-Material Flow	0.050
Robustness	0.030
Volume Flexibility	0.071
Routing Flexibility	0.053
Topography and Topology	0.036
Community Environment	0.026
Human-related Safety	0.039
Worker-related Comfort	0.037
Property-related Security	0.033
Maintenance	0.044
Sustainability	0.052
Time in Production	0.060
Time in non-Production	0.065
Production Characteristics	0.051
Other Characteristics	0.043

4.5. FUZZY AHP

Pairwise comparisons were made with five experts; the general manager, the operations manager, the vice operations manager, the member of the executive board, and the craft supervisor. Each expert made the pairwise comparisons using linguistic variables as equally important (E), moderately more important (MM), strongly more important (SM), very strongly more important (VSM), and extremely more important (EM). Tables 36-54 show the pairwise comparison matrix of one of the experts with respect to all corresponding measurements.

Tables 143-218 in Appendix show the pairwise comparison matrices of Experts 2, 3, 4, and 5, with respect to all corresponding measurements, respectively.

Table 36: Pairwise Comparison of Expert 1 with respect to Non-Inventory Cost

Non-Inventory Cost	Land Cost	Building Cost	Machinery Cost	Material Handling Cost	Labor Cost	Maintenance Cost	Future Salvage Value	Quality Cost	Capital Cost of MHE	Rearrangement Cost	Setup Cost	Energy Cost	Safety Cost	Manufacturing Operation Cost
Land Cost	E	E	MM	(MM)	E	MM	MM	MM	E	(MM)	E	MM	E	(SM)
Building Cost		E	E	(SM)	E	MM	MM	E	(MM)	(MM)	MM	E	MM	(SM)
Machinery Cost			E	(SM)	E	MM	MM	MM	(MM)	(MM)	E	MM	E	(SM)
Material Handling Cost				E	SM	VSM	VSM	VSM	SM	SM	VSM	SM	SM	(MM)
Labor Cost					E	E	MM	E	(MM)	(MM)	E	E	E	(SM)
Maintenance Cost						E	MM	E	(MM)	(SM)	E	E	E	(SM)
Future Salvage Value							E	(MM)	(MM)	(MM)	E	E	E	(SM)
Quality Cost								E	(MM)	(MM)	E	E	E	(SM)
Capital Cost of MHE									E	E	MM	MM	MM	(MM)
Rearrangement Cost										E	MM	MM	MM	(MM)
Setup Cost											E	E	E	(SM)
Energy Cost												E	(MM)	(SM)
Safety Cost													E	(SM)
Manufacturing Operation Cost														E

Table 37: Pairwise Comparison of Expert 1 with respect to Inventory Cost

Inventory Cost	Raw Material Inventory Holding Cost	WIP Inventory Holding Cost	Finished Goods Inventory Holding Cost	Backordering Cost	Loss
Raw Material Inventory Holding Cost	E	MM	SM	MM	MM
WIP Inventory Holding Cost		E	MM	E	E
Finished Goods Inventory Holding Cost			E	(MM)	(MM)
Backordering Cost				E	E
Loss					E

Table 38: Pairwise Comparison of Expert 1 with respect to Space Relationship

Space Relationship	Value-Added Area	Non-Value-Added Area	Storage Space	Dead Space	Required Area	Space Efficiency	Space Utilization
Value-Added Area	E	SM	SM	VSM	MM	MM	MM
Non-Value-Added Area		E	(MM)	MM	(MM)	(MM)	(MM)
Storage Space			E	MM	(MM)	(MM)	(MM)
Dead Space				E	(SM)	(SM)	(SM)
Required Area					E	E	E
Space Efficiency						E	E
Space Utilization							E

Table 39: Pairwise Comparison of Expert 1 with respect to Material Flow

Material Flow	Volume	Dimensions of the Aisles	Number of Loaded Travel of MHE	Number of Empty Travel of MHE	Adjacency Score	Speed	Intermodule Distances	Accessibility	Aspect Ratio	Interferences (Overlapping)
Volume	E	SM	MM	SM	MM	MM	E	MM	SM	SM
Dimensions of the Aisles		E	(MM)	E	(MM)	(MM)	(SM)	(MM)	E	E
Number of Loaded Travel of MHE			E	MM	E	E	(MM)	E	MM	MM
Number of Empty Travel of MHE				E	(MM)	(MM)	(SM)	(MM)	E	E
Adjacency Score					E	E	(MM)	E	MM	MM
Speed						E	(MM)	E	MM	MM
Intermodule Distances							E	MM	SM	SM
Accessibility								E	MM	MM
Aspect Ratio									E	E
Interferences (Overlapping)										E

Table 40: Pairwise Comparison of Expert 1 with respect to Non-Material Flow

Non-Material Flow	Information Flow (Frequency)	Personnel Flow (Frequency)	Equipment Flow (Frequency)
Information Flow (Frequency)	E	E	E
Personnel Flow (Frequency)		E	E
Equipment Flow (Frequency)			E

Table 41: Pairwise Comparison of Expert 1 with respect to Robustness

Robustness	Robustness of Equipment	Building Expansion	Free Space Availability
Robustness of Equipment	E	(MM)	(MM)
Building Expansion		E	E
Free Space Availability			E

Table 42: Pairwise Comparison of Expert 1 with respect to Volume Flexibility

Volume Flexibility	Adaptation to Variations in Production Volume	Adaptation to Variations in Demand Volume	Adaptation to Variations in Material Handling Cost	Adaptation to Variations in Material Flow	Adaptation to Variations in Equipment	Adaptation to Variations in Technology	Adaptation to Variations in Product Mix	Adaptation to Variations in Order Arrival Time	Adaptation to Variations in Processing Requirements	Adaptation to Variations in Due Date Requirements	Adaptation to Variations in Processing Time
Adaptation to Variations in Production Volume	E	E	E	MM	MM	E	E	SM	MM	MM	E
Adaptation to Variations in Demand Volume		E	E	MM	MM	MM	E	MM	MM	MM	E
Adaptation to Variations in Material Handling Cost			E	MM	MM	MM	E	MM	MM	MM	E
Adaptation to Variations in Material Flow				E	E	(MM)	(MM)	MM	E	E	(MM)
Adaptation to Variations in Equipment					E	(MM)	(MM)	MM	E	E	(MM)
Adaptation to Variations in Technology						E	E	SM	MM	MM	E
Adaptation to Variations in Product Mix							E	MM	SM	MM	E
Adaptation to Variations in Order Arrival Time								E	E	E	(MM)
Adaptation to Variations in Processing Requirements									E	E	(MM)
Adaptation to Variations in Due Date Requirements										E	(MM)
Adaptation to Variations in Processing Time											E

Table 43: Pairwise Comparison of Expert 1 with respect to Routing Flexibility

Routing Flexibility	Average Number of Alternate Routes	Accessibility of Alternate Routes
Average Number of Alternate Routes	E	E
Accessibility of Alternate Routes		E

Table 44: Pairwise Comparison of Expert 1 with respect to Topography and Topology

Topography and Topology	Natural Site Conditions and Construction	Truck Access and Circulation Pattern	Connection with External MHE
Natural Site Conditions and Construction	E	MM	E
Truck Access and Circulation Pattern		E	(MM)
Connection with External MHE			E

Table 45: Pairwise Comparison of Expert 1 with respect to Community Environment

Community Environment	Impact of Traffic Congestion and Noise	Waste Management and Pollution Control	Appearance of External or Viewable Features
Impact of Traffic Congestion and Noise	E	(MM)	MM
Waste Management and Pollution Control		E	MM
Appearance of External or Viewable Features			E

Table 46: Pairwise Comparison of Expert 1 with respect to Human-related Safety

Human-related Safety	Human Building Accidents	Human Vehicle Crossings	Human/Machine/Material/ Material Handling Interfaces	Fire / Earthquake / Evacuation
Human Building Accidents	E	MM	E	MM
Human Vehicle Crossings		E	(MM)	E
Human/Machine/Material/Material Handling Interfaces			E	MM
Fire / Earthquake / Evacuation				E

Table 47: Pairwise Comparison of Expert 1 with respect to Worker-related Comfort

Worker-related Comfort	Lighting	Aesthetics	Ease of Supervision	Noise	Ventilation / Heating	Ergonomics	Handicapped Access	Employee Satisfaction	Hygiene	Humidity	Pressure	Signs and Artifacts
Lighting	E	MM	E	E	E	(MM)	E	(MM)	(MM)	E	E	E
Aesthetics		E	(MM)	(MM)	(MM)	(SM)	(MM)	(SM)	(SM)	(MM)	E	(MM)
Ease of Supervision			E	E	E	(MM)	E	(MM)	(MM)	E	E	(MM)
Noise				E	MM	E	E	(MM)	E	E	E	E
Ventilation / Heating					E	(MM)	E	E	E	E	E	E
Ergonomics						E	MM	E	E	MM	MM	E
Handicapped Access							E	(MM)	(MM)	E	E	(MM)
Employee Satisfaction								E	E	MM	MM	E
Hygiene									E	MM	MM	E
Humidity										E	E	(MM)
Pressure											E	(MM)
Signs and Artifacts												E

Table 48: Pairwise Comparison of Expert 1 with respect to Property-related Security

Property-related Security	Theft from outside the Building	Theft from within the Building	Special Caution for Dangerous Areas
Theft from outside the Building	E	MM	E
Theft from within the Building		E	(MM)
Special Caution for Dangerous Areas			E

Table 49: Pairwise Comparison of Expert 1 with respect to Maintenance

Maintenance	Compatibility of Building Construction and MHE	Space for Maintenance Work	Appropriate Location of Maintenance Activities	Complexity of MHE
Compatibility of Building Construction and MHE	E	E	E	MM
Space for Maintenance Work		E	E	MM
Appropriate Location of Maintenance Activities			E	MM
Complexity of MHE				E

Table 50: Pairwise Comparison of Expert 1 with respect to Sustainability

Sustainability	Number of Reused / Recycled Materials	Environmental Sustainability Index	Environmental Performance Index
Number of Reused / Recycled Materials	E	(MM)	(MM)
Environmental Sustainability Index		E	E
Environmental Performance Index			E

Table 51: Pairwise Comparison of Expert 1 with respect to Time in Production

Time in Production	Production Time	Setup Time	Throughput Time	Overall Processing Time	Cycle Time	Idle Time
Production Time	E	MM	E	E	MM	SM
Setup Time		E	(MM)	(MM)	E	MM
Throughput Time			E	E	MM	SM
Overall Processing Time				E	MM	SM
Cycle Time					E	MM
Idle Time						E

Table 52: Pairwise Comparison of Expert 1 with respect to Time in non-Production

Time in Non-Production	Storage Time	Retrieval Time	Loading Time	Unloading Time	Stoppages	Transportation Time
Storage Time	E	E	(MM)	(MM)	MM	0,33
Retrieval Time		E	(MM)	(MM)	MM	0,33
Loading Time			E	E	MM	E
Unloading Time				E	MM	E
Stoppages					E	(MM)
Transportation Time						E

Table 53: Pairwise Comparison of Expert 1 with respect to Production Characteristics

Production Characteristics	Production Volume	Production / Machine Capacity	Total Quality Management (Kaizen)	Quality of the Product	Raw Material Inventory	WIP Inventory	Finished Goods Inventory
Production Volume	E	MM	SM	E	E	MM	SM
Production / Machine Capacity		E	MM	(MM)	(MM)	E	MM
Total Quality Management (Kaizen)			E	(SM)	(SM)	(MM)	E
Quality of the Product				E	E	MM	SM
Raw Material Inventory					E	MM	SM
WIP Inventory						E	MM
Finished Goods Inventory							E

Table 54: Pairwise Comparison of Expert 1 with respect to Other Characteristics

Other Characteristics	Average Machine Utilization	Size	Shape of Departments	Shape of Machines	Number of Departments	Number of Machines	Average Availability of Facilities	Manpower Requirements (Skills, Qualifications)
Average Machine Utilization	E	SM	MM	MM	MM	MM	MM	MM
Size		E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Shape of Departments			E	E	E	E	E	E
Shape of Machines				E	E	E	E	E
Number of Departments					E	E	E	E
Number of Machines						E	E	E
Average Availability of Facilities							E	E
Manpower Requirements (Skills, Qualifications)								E

After gathering the geometric mean of pairwise comparisons of five experts and the necessary calculations, the weights of measurements were found, as shown in Table 55:

Table 55: The Weights of Sub-Criteria and the Measurements

MAIN CRITERIA	**SUB-CRITERIA**	**WEIGHTS OF SUB-CRITERIA**	**MEASUREMENT**	**WEIGHTS OF MEASUREMENTS**
Cost				
	Non-Inventory Cost	0.121		
			Land Cost	0.05
			Building Cost (Floor Construction Cost)	0.03
			Production Machinery Cost	0.03
			Material Handling Cost	0.30
			Labor Cost	0.02
			Maintenance Cost	0.02
			Future Salvage Value	0.02
			Quality Cost	0.02
			Capital Cost of Material Handling Equipment (Investment)	0.07
			Rearrangement Cost	0.10
			Setup Cost	0.02
			Energy Cost	0.02

			Safety Cost	0.02
			Manufacturing Operation Cost	0.30
	Inventory Cost	0.029		
			Raw Material Inventory Holding Cost	0.50
			WIP Inventory Holding Cost	0.24
			Finished Goods Inventory Holding Cost	0.07
			Backordering Cost	0.11
			Loss (Production+Damage+Spoilage+Obsolescence)	0.09
Flow				
	Space Relationship	0.072		
			Value-Added Area	0.50
			Non-Value Added Area	0.03
			Storage Space (m^3)	0.06
			Dead (Empty) Space (m^3)	0.04
			Required Area (Area Requirements)	0.07
			Space Efficiency (m^3)	0.14
			Space Utilization (m^3)	0.16
	Material Flow	0.089		
			Volume	0.24
			Dimensions of the Aisles	0.03
			Number of Loaded Travel of Material Handling Equipment	0.07
			Number of Empty Travel of Material Handling Equipment	0.03
			Adjacency Score	0.11
			Speed	0.09
			Intermodule Distances	0.33
			Accessibility	0.04
			Aspect Ratio	0.03
			Interferences (Overlapping)	0.03
	Non-Material Flow	0.050		
			Information Flow (Frequency)	0.40
			Personnel Flow (Frequency)	0.32
			Equipment Flow (Frequency)	0.28
Flexibility				
	Robustness	0.030		
			Robustness of Equipment	0.31
			Building Expansion	0.33
			Free Space Availability	0.36
	Volume Flexibility	0.071		
			Adaptation to Variations in Production Volume	0.12
			Adaptation to Variations in Demand Volume	0.18
			Adaptation to Variations in Material Handling Cost	0.09
			Adaptation to Variations in Material Flow	0.05
			Adaptation to Variations in Equipment	0.06
			Adaptation to Variations in Technology	0.12
			Adaptation to Variations in Product Mix	0.17
			Adaptation to Variations in Order Arrival Time	0.04

			Adaptation to Variations in Processing Requirements	0.04
			Adaptation to Variations in Due Date Requirements	0.04
			Adaptation to Variations in Processing Time	0.08
	Routing Flexibility	0.053		
			Average Number of Alternate Routes	0.50
			Accessibility of Alternate Routes	0.50
Surrounding Environment				
	Topography and Topology	0.036		
			Natural Site Conditions and Construction	0.32
			Truck Access and Circulation Pattern	0.20
			Connection with External Material Handling Equipment	0.48
	Community Environment	0.026		
			Impact of Traffic Congestion and Noise	0.31
			Waste Management and Pollution Control	0.44
			Appearance of External or Viewable Features	0.25
Environment Quality				
	Human-related Safety	0.039		
			Human Building Accidents	0.30
			Human Vehicle Crossings	0.10
			Human/Machine/Material/ Material Handling Interfaces	0.31
			Fire / Earthquake / Evacuation	0.29
	Worker-related Comfort	0.037		
			Lighting	0.06
			Aesthetics	0.03
			Ease of Supervision	0.14
			Noise	0.07
			Ventilation/Heating	0.05
			Ergonomics	0.18
			Handicapped Access	0.04
			Employee Satisfaction	0.20
			Hygiene	0.09
			Humidity	0.04
			Pressure	0.04
			Signs & Artifacts	0.08
	Property-related Security	0.033		
			Theft from outside the Building	0.28
			Theft from within the Building	0.15
			Special Caution for Dangerous Areas	0.56
	Maintenance	0.044		
			Compatibility of Building Construction and Material Handling Equipment	0.36
			Space for Maintenance Work	0.18

			Appropriate Location of Maintenance Activities	0.32
			Complexity of Material Handling Equipment	0.13
	Sustainability	0.052		
			Number of Reused/Recycled Materials	0.19
			Environmental Sustainability Index	0.31
			Environmental Performance Index	0.50
Time				
	Time in Production	0.060		
			Production Time	0.30
			Setup Time	0.06
			Throughput Time	0.15
			Overall Processing Time	0.36
			Cycle Time	0.07
			Idle Time	0.06
	Time in non-Production	0.065		
			Storage Time	0.09
			Retrieval Time	0.08
			Loading Time	0.23
			Unloading Time	0.18
			Stoppages	0.05
			Transportation Time (Flow Time)	0.37
Characteristics				
	Production Characteristics	0.051		
			Production Volume	0.25
			Production/Machine Capacity	0.17
			Total Quality Management (Kaizen)	0.04
			Quality of Product	0.25
			Raw Material Inventory	0.18
			WIP Inventory	0.07
			Finished Goods Inventory	0.04
	Other Characteristics	0.043		
			Average Machine Utilization	0.37
			Size (Department, Block, Cell)	0.04
			Shape of Departments	0.08
			Shape of Machines	0.07
			Number of Departments	0.08
			Number of Machines	0.08
			Average Availability of Facilities	0.19
			Manpower Requirements (Skills, Qualifications)	0.09

The fuzzy AHP result seems consistent. According to the consistency check analysis, all consistency ratios are less than 10%. Table 56 shows the consistency ratios for all sub-criteria.

Table 56: Consistency Ratios

Sub-Criteria	Consistency Ratios
Non-Inventory Cost	9%
Inventory Cost	6%
Space Relationship	7%
Material Flow	6%
Non-Material Flow	1%
Robustness	0%
Volume Flexibility	2%
Routing Flexibility	0%
Topology and Topography	2%
Community Environment	5%
Human-related Safety	2%
Worker-related Comfort	3%
Property-related Security	5%
Maintenance	2%
Sustainability	3%
Time in Production	3%
Time in Non-Production	5%
Production Characteristics	4%
Other Characteristics	4%

4.6. PERFORMANCE ASSESSMENT MODEL

The weights of sub-criteria and the weights of the measurements were found using fuzzy ANP and fuzzy AHP techniques, respectively. Those weights were used to find the overall performance score of the company.

All found weights were multiplied by the performance scores of the layout of the company in order to calculate the overall performance assessment score.

The performance score is determined between 0 and 1, because, the overall performance score will be identified as a percentage. Since all the techniques are integrated in fuzzy set theory, the performance scores are also fuzzy. The corresponding performance scores for each measurement were evaluated during a group session with the five experts; the general manager, the operations manager, the vice operations manager, the member of the executive board, and the craft supervisor. The linguistic variables for indicating the judgments for the performance scores can be seen in Table 57.

Table 57: Fuzzy Linguistic Scale

Linguistic terms	Triangular fuzzy numbers
Very high (VH)	(0.75,1.0,1.0)
High (H)	(0.5,0.75,1.0)
Average (A)	(0.25,0.5,0.75)
Low (L)	(0,0.25,0.5)
Very low (VL)	(0,0,0.25)

The corresponding fuzzy numbers are defuzzified using CFCS method. Table 58 shows the weights of sub-criteria, the weights of measurements, the values of corresponding performance scores, the weighted scores and the overall performance score of the layout. The weighted scores show the performance score of all measurements individually, the overall score shows the total performance score.

Table 58: The Overall Performance Score of the Layout

MAIN CRITERIA	SUB-CRITERIA	WEIGHTS OF SUB-CRITERIA	MEASUREMENT	WEIGHTS OF MEASURE MENTS	PERFOR MANCE SCORES	INDIVIDUAL WEIGHTS	SCORES	COLLECTIVE SCORES
Cost								
	Non-Inventory Cost	0.121						0.067
			Land Cost	0.05	0.733	0.006	0.004	
			Building Cost (Floor Construction Cost)	0.03	0.733	0.004	0.003	
			Production Machinery Cost	0.03	0.733	0.003	0.002	
			Material Handling Cost	0.30	0.500	0.036	0.018	
			Labor Cost	0.02	0.500	0.003	0.001	
			Maintenance Cost	0.02	0.500	0.002	0.001	
			Future Salvage Value	0.02	0.267	0.002	0.001	
			Quality Cost	0.02	0.733	0.002	0.002	
			Capital Cost of Material Handling Equipment (Investment)	0.07	0.733	0.008	0.006	
			Rearrangement Cost	0.10	0.500	0.012	0.006	
			Setup Cost	0.02	0.733	0.002	0.002	
			Energy Cost	0.02	0.733	0.002	0.002	
			Safety Cost	0.02	0.733	0.002	0.002	
			Manufacturing Operation Cost	0.30	0.500	0.036	0.018	
	Inventory Cost	0.029						0.025
			Raw Material Inventory Holding Cost	0.50	0.967	0.015	0.014	
			WIP Inventory Holding Cost	0.24	0.733	0.007	0.005	

			Finished Goods Inventory Holding Cost	0.07	0.967	0.002	0.002	
			Backordering Cost	0.11	0.733	0.003	0.002	
			Loss (Production+Damage+ Spoilage+Obsolescenc e)	0.09	0.733	0.003	0.002	
Flow								
	Space Relationship	0.072						0.045
			Value-Added Area	0.50	0.733	0.036	0.026	
			Non-Value Added Area	0.03	0.500	0.002	0.001	
			Storage Space (m^3)	0.06	0.267	0.005	0.001	
			Dead (Empty) Space (m^3)	0.04	0.267	0.003	0.001	
			Required Area (Area Requirements)	0.07	0.500	0.005	0.002	
			Space Efficiency (m^3)	0.14	0.733	0.010	0.007	
			Space Utilization (m^3)	0.16	0.500	0.011	0.006	
	Material Flow	0.089						0.060
			Volume	0.24	0.733	0.022	0.016	
			Dimensions of the Aisles	0.03	0.733	0.003	0.002	
			Number of Loaded Travel of Material Handling Equipment	0.07	0.500	0.006	0.003	
			Number of Empty Travel of Material Handling Equipment	0.03	0.500	0.002	0.001	
			Adjacency Score	0.11	0.733	0.010	0.007	
			Speed	0.09	0.500	0.008	0.004	
			Intermodule Distances	0.33	0.733	0.029	0.022	
			Accessibility	0.04	0.500	0.003	0.002	
			Aspect Ratio	0.03	0.500	0.003	0.001	
			Interferences (Overlapping)	0.03	0.733	0.003	0.002	
	Non-Material Flow	0.050						0.033
			Information Flow (Frequency)	0.40	0.733	0.020	0.015	
			Personnel Flow (Frequency)	0.32	0.733	0.016	0.012	
			Equipment Flow (Frequency)	0.28	0.500	0.014	0.007	
Flexibility								
	Robustness	0.030						0.020
			Robustness of Equipment	0.31	0.500	0.009	0.005	
			Building Expansion	0.33	0.733	0.010	0.007	
			Free Space Availability	0.36	0.733	0.011	0.008	
	Volume Flexibility	0.071						0.056
			Adaptation to Variations in Production Volume	0.12	0.967	0.009	0.009	
			Adaptation to Variations in Demand Volume	0.18	0.967	0.013	0.012	
			Adaptation to Variations in Material Handling Cost	0.09	0.500	0.007	0.003	

			Adaptation to Variations in Material Flow	0.05	0.733	0.004	0.003	
			Adaptation to Variations in Equipment	0.06	0.733	0.004	0.003	
			Adaptation to Variations in Technology	0.12	0.500	0.009	0.004	
			Adaptation to Variations in Product Mix	0.17	0.967	0.012	0.011	
			Adaptation to Variations in Order Arrival Time	0.04	0.733	0.003	0.002	
			Adaptation to Variations in Processing Requirements	0.04	0.733	0.003	0.002	
			Adaptation to Variations in Due Date Requirements	0.04	0.733	0.003	0.002	
			Adaptation to Variations in Processing Time	0.08	0.733	0.005	0.004	
	Routing Flexibility	0.053						0.045
			Average Number of Alternate Routes	0.50	0.733	0.027	0.019	
			Accessibility of Alternate Routes	0.50	0.967	0.027	0.026	
Surrounding Environment								
	Topography and Topology	0.036						0.029
			Natural Site Conditions and Construction	0.32	0.967	0.012	0.011	
			Truck Access and Circulation Pattern	0.20	0.733	0.007	0.005	
			Connection with External Material Handling Equipment	0.48	0.733	0.017	0.013	
	Community Environment	0.026						0.021
			Impact of Traffic Congestion and Noise	0.31	0.733	0.008	0.006	
			Waste Management and Pollution Control	0.44	0.967	0.012	0.011	
			Appearance of External or Viewable Features	0.25	0.500	0.007	0.003	
Environment Quality								
	Human-related Safety	0.039						0.035
			Human Building Accidents	0.30	0.733	0.011	0.008	
			Human Vehicle Crossings	0.10	0.967	0.004	0.004	
			Human/Machine/Material/ Material Handling Interfaces	0.31	0.967	0.012	0.012	
			Fire / Earthquake / Evacuation	0.29	0.967	0.011	0.011	
	Worker-related Comfort	0.037						0.023
			Lighting	0.06	0.967	0.002	0.002	

			Aesthetics	0.03	0.267	0.001	0.000		
			Ease of Supervision	0.14	0.733	0.005	0.004		
			Noise	0.07	0.267	0.003	0.001		
			Ventilation/Heating	0.05	0.500	0.002	0.001		
			Ergonomics	0.18	0.500	0.006	0.003		
			Handicapped Access	0.04	0.733	0.001	0.001		
			Employee Satisfaction	0.20	0.733	0.007	0.005		
			Hygiene	0.09	0.733	0.003	0.002		
			Humidity	0.04	0.500	0.001	0.001		
			Pressure	0.04	0.500	0.001	0.001		
			Signs & Artifacts	0.08	0.733	0.003	0.002		
	Property-related Security	0.033						0.027	
			Theft from outside the Building	0.28	0.733	0.009	0.007		
			Theft from within the Building	0.15	0.500	0.005	0.003		
			Special Caution for Dangerous Areas	0.56	0.967	0.019	0.018		
	Maintenance	0.044						0.038	
			Compatibility of Building Construction and Material Handling Equipment	0.36	0.967	0.016	0.015		
			Space for Maintenance Work	0.18	0.967	0.008	0.008		
			Appropriate Location of Maintenance Activities	0.32	0.733	0.014	0.010		
			Complexity of Material Handling Equipment	0.13	0.733	0.006	0.004		
	Sustainability	0.052						0.030	
			Number of Reused/Recycled Materials	0.19	0.267	0.010	0.003		
			Environmental Sustainability Index	0.31	0.500	0.016	0.008		
			Environmental Performance Index	0.50	0.733	0.026	0.019		
Time									
	Time in Production	0.060						0.039	
			Production Time	0.30	0.733	0.018	0.013		
			Setup Time	0.06	0.967	0.004	0.003		
			Throughput Time	0.15	0.733	0.009	0.007		
			Overall Processing Time	0.36	0.500	0.022	0.011		
			Cycle Time	0.07	0.733	0.004	0.003		
			Idle Time	0.06	0.500	0.003	0.002		
	Time in non-Production	0.065						0.049	
			Storage Time	0.09	0.733	0.006	0.004		
			Retrieval Time	0.08	0.733	0.005	0.004		
			Loading Time	0.23	0.967	0.015	0.015		
			Unloading Time	0.18	0.967	0.011	0.011		
			Stoppages	0.05	0.967	0.003	0.003		
			Transportation Time (Flow Time)	0.37	0.500	0.024	0.012		
Characteristics									
	Production Characteristics	0.051						0.030	

			Production Volume	0.25	0.500	0.013	0.006	
			Production/Machine Capacity	0.17	0.733	0.009	0.006	
			Total Quality Management (Kaizen)	0.04	0.033	0.002	0.000	
			Quality of Product	0.25	0.733	0.013	0.009	
			Raw Material Inventory	0.18	0.500	0.009	0.005	
			WIP Inventory	0.07	0.500	0.003	0.002	
			Finished Goods Inventory	0.04	0.967	0.002	0.002	
	Other Characteristic s	0.043						0.025
			Average Machine Utilization	0.37	0.500	0.016	0.008	
			Size (Department, Block, Cell)	0.04	0.733	0.002	0.001	
			Shape of Departments	0.08	0.500	0.003	0.002	
			Shape of Machines	0.07	0.733	0.003	0.002	
			Number of Departments	0.08	0.733	0.003	0.002	
			Number of Machines	0.08	0.500	0.003	0.002	
			Average Availability of Facilities	0.19	0.733	0.008	0.006	
			Manpower Requirements (Skills, Qualifications)	0.09	0.500	0.004	0.002	
								0.698

The performance scores of Non-Inventory Cost was found to be 0.067; Inventory Cost, 0.025; Space Relationship, 0.045; Material Flow, 0.060; Non-Material Flow, 0.033; Robustness, 0.020; Volume Flexibility, 0.056; Routing Flexibility, 0.045; Topography and Topology, 0.029; Community Environment, 0.021; Human-related Safety, 0.035; Worker-related Comfort, 0.023; Property-related Security, 0.027; Maintenance, 0.038; Sustainability, 0.030, Time in Production, 0.039; Time in non-Production, 0.049; Production Characteristics, 0.030; and Other Characteristics, 0.025. The overall performance score was found to be 0.698, in other words, 69.8%, which means that the layout of the company is performing 69.8% efficient and effective.

4.7. OUTCOMES

The overall performance score is highly related with the individual performance scores and the individual weights. In order to increase the performance score of the company, they should improve the low-judged individual performance scores, and maintain the performance of very high-judged individual performance scores.

The individual scores of “Material Handling Cost”, “Manufacturing Operation Cost”, “Overall Processing Time”, and “Transportation Time”, were judged as “Average”; therefore, in order to increase the overall performance score, these highly-weighted items should be improved.

Other highly-weighted items, such as “Value-Added Area”, “Volume”, Intermodule Distances”, “Information Flow”, “Average Number of Alternate Routes”, and “Environmental Performance Index” are judged as “High”; therefore, in order to increase the overall performance score, these highly-weighted items should be improved. For example, if the “Intermodule Distances” performance score is improved, then the “Material Handling Cost” score will automatically improve; therefore, the overall performance score of the layout will improve by both the improvement of “Intermodule Distances” and “Material Handling Cost” scores.

Other highly-weighted items such as “Accessibility of Alternate Routes” and “Special Caution for Dangerous Areas” are judged as “Very High”; therefore, in order to keep the overall performance score, those highly-weighted items should maintain their high performances.

CHAPTER 5: CONCLUSION

The facility layout problem was one of the main research topics in industrial engineering and operations management areas. The majority of the research focused on the modelling of the layout, usually the development of mathematical, heuristics, metaheuristics, and simulation models to constitute a layout. However, the evaluation of performance of layout has been neglected, and is an important area for study.

The models for the evaluation of the layout, in fact, evaluate the performance of the operations. The evaluation of layout should examine the main characteristics of layouts before the operation started to avoid high costs and loss of time due to the re-layout process. Therefore, for a layout performance evaluation, the indices, i.e., the criteria, should be specified in order to gain insight for the impacts for a layout alternative (Lin and Sharp, 1999).

Within this context, this dissertation aims to present a new hybrid multi-criteria decision-making model to assess the performance of the layout. With a systematic and very detailed literature review, the criteria set and the corresponding measurements were determined. There are three major contributions of this dissertation. Firstly, we have categorized the indices as Criteria, Sub-Criteria, and Measurement. Secondly, the criteria set are an extended set to fully describe the dimensions of the layout effectiveness. Finally, we have integrated four different MCDM techniques into a hybrid model for the performance assessment.

The application was conducted in an elevator and escalator manufacturing firm located in Maltepe, Menemen, Izmir. Five experts from the firm participated in the survey; the general manager, the operations manager, the vice operations manager, the member of the executive board, and the craft supervisor.

The model, called hybrid multi criteria decision-making (MCDM) model, consists of different MCDM techniques. Firstly, fuzzy TISM technique is applied in order to determine the relationships between a set of criteria. Then, fuzzy DEMATEL technique is employed to identify the causal relationships. In the next step, using the output of the fuzzy DEMATEL method, inner-dependence matrix, fuzzy ANP technique is applied in order to determine the weights of sub-criteria. After determining the weights of the sub-criteria, the weights of corresponding measurements are found using fuzzy AHP technique. Thus, the structural causal relationship, the weights of sub-criteria, and the weights of the measurements are found. All found weights are multiplied by the performance scores of all measurements, which are evaluated in a collective session, in order to find the overall performance assessment score. The sum of the performance scores gives the overall performance score, which represents the level of efficiency and effectiveness of the layout.

"Non-Inventory Cost" was found as the most important sub-criterion with a weight of 0.121. This means that, most important criterion to improve the performance of the layout is Non-Inventory Cost. The 2nd most important sub-criterion is found as the "Material Flow" with a weight of 0.089. "Space Relationship", with a weight of 0.072 can be identified as 3rd most important sub-criterion. From this analysis, it can be understood that, material handling cost plays a major role for the performance assessment of the layout, because the most important criteria are especially related with material handling activity.

"Volume Flexibility", with a weight of 0.071 can be identified as the 4th important sub-criterion. This shows that variations in the production process are also important part of performance assessment activity.

The 5th and the 6th most important criteria were found as "Time in Non-production", and "Time in Production", with weights of 0.065, and 0.060, respectively. It can be understood that, whether it is spent in production or not, time is an important criterion affecting the layout's performance.

"Routing Flexibility", "Sustainability", "Production Characteristics", and "Non-Material Flow" were prioritized as the 7th, 8th, 9th, and 10th criteria with the weights of, 0.053, 0.052, 0.051, and 0.050, respectively.

"Maintenance", "Other Characteristics", "Human-related Safety", "Worker-related Comfort", "Topography and Topology", "Property-related Security", "Robustness", "Inventory Cost", and "Community Environment" were ranked from 11th to 19th, with the weights of 0.044, 0.043, 0.039, 0.037, 0.036, 0.033, 0.030, 0.029, and 0.026, respectively.

Within the "Non-Inventory Cost" cluster, "Material Handling Cost" and the "Manufacturing Operation Cost" both had an importance weight of 0.30; therefore, they can be stated as the most important non-inventory costs.

"Intermodule Distances" were found as the most important criterion with a weight of 0.33, and the "Volume" was found as the 2nd, with a weight of 0.24, within the "Material Flow" cluster. This also emphasizes the importance of material handling activities.

Within the "Space Relationship" cluster, "Value-Added Area" was the most important measurement, with a weight of 0.50, emphasizing its role in determining the performance score of the layout.

With a weight of 0.18, "Adaptations to Variations to the Demand Volume" was the most important measurement within the "Volume Flexibility" cluster. It seems natural, because, the company usually faces with the variations in demand based on seasonal requirements.

"Transportation Time", "Loading Time", and "Unloading Time", the most important measurements within the "Time in Non-Production" cluster, had the weights of 0.37, 0.23, and 0.18, respectively. It also seems natural, because these measurements are closely related with the material handling activities.

Within the “Time in Production” cluster, “Overall Processing Time”, and “Production Time” were the found as the most important measurements, with the weights of 0.36, and 0.30, respectively. These high weights of those measurements reflect the importance of production process in the performance of the layout.

There are already two measurements within the “Routing Flexibility” cluster, namely, “Average Number of Alternate Routes” and “Accessibility of Alternate Routes”. They both had weights of 0.50, in other words, they have equal importance weight in the assessment of layout’s performance.

“Environmental Performance Index” was the most important measurement within the “Sustainability” cluster, showing that the company has environmental consciousness.

“Production Volume” and “Quality of the Product” both have weights of 0.25 within the “Production Characteristics” cluster. This result emphasizes that two conflicting measurements, “Production Volume” and “Quality of the Product” were important for the layout performance. The best option is to provide a high standard for both, because a tradeoff may dramatically decrease the performance score of the layout.

There were already three measurements within the “Non-Material Flow” cluster, namely, “Information Flow”, “Personnel Flow”, and “Equipment Flow” with importance weights of 0.40, 0.32, and 0.28, respectively. These values emphasize that layout performance is affected by non-material flows.

Within the “Maintenance” cluster, “Compatibility of Building Construction and Material Handling Equipment” and “Appropriate Location of Maintenance Activities” had weights of 0.36, and 0.32, respectively. “Average Machine Utilization” was the most important measurement within the “Other Characteristics” cluster, with a weight of 0.37. “Human/Machine/Material Handling Interfaces”, “Human Building Accidents”, and “Fire/Earthquake/Evacuation” had a total importance weight of 0.90 within the “Human-related Safety” cluster. “Employee Satisfaction” was the most important measurement within the “Worker-related Comfort” cluster, with a weight of 0.20; “Connection with External Material Handling Equipment” within the “Topography and Topology” cluster, with a weight of 0.48; “Special Caution for Dangerous Areas” for the “Property-related Security” with a weight of 0.56; “Free Space Availability” within the “Robustness” cluster, with a weight of 0.36; “Raw Material Inventory Holding Cost” within the “Inventory Cost” cluster, with a weight of 0.50; and finally, “Waste Management and Pollution Control” within the “Community Environment” cluster, with a weight of 0.44.

The performance scores of each measurement are scaled in a collective session with very detailed indexes. Linguistic variables were used to find the performance score of each sub-criterion and the corresponding measurements. Accordingly, the performance scores of Non-Inventory Cost was found 0.067; Inventory Cost, 0.025; Space Relationship, 0.045; Material Flow, 0.060; Non-Material Flow, 0.033; Robustness, 0.020; Volume Flexibility, 0.056; Routing Flexibility, 0.045; Topography and Topology, 0.029; Community Environment, 0.021; Human-related Safety, 0.035; Worker-related Comfort, 0.023; Property-related Security, 0.027; Maintenance, 0.038; Sustainability, 0.030, Time in Production, 0.039; Time in non-Production, 0.049; Production Characteristics, 0.030; and finally, Other Characteristics, 0.025.

The overall performance score was found to be 0.698, in other words, 69.8%, which means the layout of the company is performing 69.8% efficient and effective.

The overall performance score is highly related with the individual performance scores and the individual weights. In order to increase the performance score, the company should improve the low-judged individual performance scores, and maintain the performance of very high-judged individual performance scores.

The limitation of this research is that, as all of the MCDM applications, the research includes subjective judgments.

Further research may concentrate on the application in different companies in the escalator industry, and other manufacturing industries, because the model can be generalized.

APPENDIX

Table 59: Pairwise Comparison of Expert 2

EXPERT 2	Other Characteristics	Production Characteristics	Time in non-Production	Time in Production	Sustainability	Maintenance	Property-related Security	Worker-related Comfort	Human-related Safety	Community Environment	Topography and Topology	Routing Flexibility	Volume Flexibility	Robustness	Non-Material Flow	Material Flow	Space Relationship	Inventory Cost
Non-Inventory Cost	X(L,H)	X(VH,H)	X(H,VH)	X(H,VH)	X(H)	X(H)	X(L)	X(L)	X(L)	O(NO)	X(VL,H)	X(L,VH)	X(H,VH)	O(NO)	X(H,VH)	X(VH)	X(H,L)	X(H)
Inventory Cost	A(L)	A(H)	X(L)	X(L,VH)	A(H)	X(L,H)	X(L)	O(NO)	O(NO)	O(NO)	O(NO)	O(NO)	X(L,H)	A(VH)	O(NO)	V(L)	X(H,VH)	
Space Relationship	X(L,H)	X(H)	X(VH)	X(VH,H)	A(L)	X(H,L)	V(L)	X(L)	X(L)	X(L,H)	X(L,H)	X(H)	X(H)	X(H)	X(H,VH)	X(H,VH)		
Material Flow	X(L,H)	X(H)	X(VH)	X(L,H)	X(H)	V(L)	A(H)	A(H)	X(L,H)	A(L)	X(L,H)	X(H,VH)	X(H,VH)	X(L)	X(H)			
Non-Material Flow	A(H)	X(L,H)	X(H)	X(H)	X(L,H)	O(NO)	A(L)	X(H)	X(H)	A(L)	X(L,H)	X(L,H)	O(NO)	V(L)				
Robustness	A(L)	X(H,L)	X(H,L)	X(L)	X(H)	X(L)	A(L)	X(L)	X(L)	O(NO)	V(L)	X(VH,H)	X(VH,H)					
Volume Flexibility	V(L)	X(H)	X(VH,H)	X(L,H)	X(H)	X(L)	A(L)	A(L)	A(L)	A(L)	A(L)	X(H)						
Routing Flexibility	O(NO)	X(H)	X(VH,H)	X(L,H)	X(H)	A(L)	A(H)	A(L)	A(L)	A(L)	X(L)							
Topography and Topology	A(H)	X(VL,L)	V(H)	V(H)	X(L,H)	A(L)	A(L)	X(L)	X(L)	O(NO)								
Community Environment	A(H)	X(L)	O(NO)	O(NO)	X(L,H)	A(L)	A(H)	X(H)	X(H)									
Human-related Safety	A(L)	X(L,H)	X(H,L)	V(H)	X(L,H)	A(H)	A(H)	X(H)										
Worker-related Comfort	X(L)	X(L,H)	X(L)	V(L)	X(L,H)	A(H)	A(H)											
Property-related Security	X(L)	X(L,H)	X(H,L)	O(NO)	X(H)	X(H)												
Maintenance	X(L)	X(H)	X(H)	X(H)	X(H)													
Sustainability	X(L,H)	X(H,VL)	X(H)	X(H)														
Time in Production	X(H,L)	X(H)	X(H)															
Time in non-Production	X(H)	X(L)																
Production Characteristics	X(L)																	

Table 60: Pairwise Comparison of Expert 3

EXPERT 3	Other Characteristics	Production Characteristics	Time in non-Production	Time in Production	Sustainability	Maintenance	Property-related Security	Worker-related Comfort	Human-related Safety	Community Environment	Topography and Topology	Routing Flexibility	Volume Flexibility	Robustness	Non-Material Flow	Material Flow	Space Relationship	Inventory Cost
Non-Inventory Cost	X(L,VL)	X(L,H)	X(VH)	X(VH,VL)	X(H)	X(L,H)	X(L)	X(L)	X(H,L)	X(VH,VL)	X(H,VH)	X(VL,H)	A(VH)	X(L,VL)	X(H,VH)	X(L,VH)	X(H)	X(H,L)
Inventory Cost	A(H)	X(L,VH)	A(H)	A(VH)	X(L,VH)	X(H)	X(L)	A(L)	O(NO)	A(VL)	O(NO)	A(L)	X(VH,H)	X(L,VH)	A(H)	A(L)	X(L,H)	
Space Relationship	X(L,VH)	X(L,H)	X(H)	X(H)	X(L,H)	V(L)	A(VL)	X(L)	A(L)	X(H,L)	X(H,L)	X(H,VH)	X(H,VH)	X(VL)	X(H,VH)	X(VH)		
Material Flow	A(L)	X(H,VH)	X(H)	X(L,VH)	X(H,VH)	X(L,H)	A(VH)	A(L)	A(H)	O(NO)	X(L,VH)	X(VH)	X(VH)	X(H)	X(H)			
Non-Material Flow	A(H)	X(H)	X(H)	X(L,VL)	X(L,H)	X(H,L)	A(H)	X(VL,L)	A(H)	O(NO)	X(L,VH)	X(VH,H)	X(L,VH)	X(L,VL)				
Robustness	V(L)	V(VH)	X(VH,L)	X(VH,L)	A(L)	X(H)	A(L)	O(NO)	X(VL)	A(VL)	A(VL)	X(VL,H)	V(H)					
Volume Flexibility	V(L)	X(VH,L)	X(VH,L)	X(VH,H)	X(H,L)	A(H)	X(L)	A(L)	O(NO)	O(NO)	X(L)	X(H,VH)						
Routing Flexibility	V(H)	X(H,L)	X(VH,H)	X(VH,H)	X(H)	X(L)	A(H)	V(L)	X(L,H)	O(NO)	X(L)							
Topography and Topology	A(H)	A(L)	V(H)	V(VL)	X(L,H)	V(H)	X(H,VH)	X(VH,VL)	V(H)	X(L)								
Community Environment	V(VL)	X(VL,L)	V(L)	V(H)	X(VH,H)	V(L)	X(H,VL)	X(VH,VL)	V(VH)									
Human-related Safety	X(H,L)	X(L,H)	X(H)	X(H)	X(L,H)	A(H)	A(VL)	X(H)										
Worker-related Comfort	X(H)	X(H)	X(H,L)	X(H)	X(VL,H)	A(H)	A(VL)											
Property-related Security	A(L)	O(NO)	X(L,H)	V(L)	A(H)	X(VL,L)												
Maintenance	X(L,H)	X(H,VH)	X(H)	X(H,VL)	X(H,L)													
Sustainability	X(H)	X(H,VL)	X(VH,L)	V(H)														
Time in Production	X(VH,L)	X(L,VH)	X(H)															
Time in non-Production	X(H,L)	X(L,VL)																
Production Characteristics	X(L)																	

Table 61: Pairwise Comparison of Expert 4

EXPERT 4	Other Characteristics	Production Characteristics	Time in non-Production	Time in Production	Sustainability	Maintenance	Property-related Security	Worker-related Comfort	Human-related Safety	Community Environment	Topography and Topology	Routing Flexibility	Volume Flexibility	Robustness	Non-Material Flow	Material Flow	Space Relationship	Inventory Cost
Non-Inventory Cost	X(L,H)	X(H)	X(VH)	X(VH,VL)	X(H,VH)	X(H)	X(L,VH)	X(L)	X(L,H)	O(NO)	X(VL,H)	X(VL,L)	X(H)	A(VL)	X(H,VH)	X(VH,H)	X(VH,L)	X(H)
Inventory Cost	A(L)	X(L,H)	X(VL,L)	X(L,VH)	A(VH)	X(H)	X(L,H)	V(VL)	A(VH)	O(NO)	O(NO)	A(L)	X(H)	A(VH)	O(NO)	X(L,H)	X(VH)	
Space Relationship	X(L,H)	X(H)	X(VH)	X(VH,H)	A(L)	X(H,L)	X(L,VH)	X(L)	X(L,H)	X(H)	X(L,H)	X(H,VH)	X(H,VH)	X(H,VL)	X(H,VH)	X(H)		
Material Flow	X(L,H)	X(H)	X(H)	X(H,VH)	X(H)	V(H)	X(H,VH)	X(L,H)	X(H)	X(H,VL)	X(H)	X(H,VH)	X(H,VH)	X(H)	X(H)			
Non-Material Flow	A(H)	X(L,H)	X(VH,H)	X(H,VL)	X(L,H)	O(NO)	A(H)	X(H)	X(H)	A(VL)	X(L,H)	X(L,H)	A(VH)	X(L,VL)				
Robustness	X(L)	V(VH)	X(VH,L)	V(VH)	A(L)	X(H,L)	A(L)	A(L)	X(VL)	O(NO)	O(NO)	X(VL,L)	X(H)					
Volume Flexibility	V(L)	X(VH,L)	X(VH,H)	X(VH)	X(H,L)	X(H,L)	X(H,L)	X(H,L)	X(VH,L)	A(VL)	X(L)	X(L,VH)						
Routing Flexibility	V(VH)	X(VH,L)	X(VH,H)	X(VH,H)	X(H,L)	X(H,L)	X(H,VH)	X(H,L)	X(VH)	A(L)	X(L)							
Topography and Topology	A(H)	X(L,VL)	X(H,VL)	V(H)	X(L,H)	A(L)	A(VH)	X(L)	V(L)	A(VL)								
Community Environment	X(VL,H)	X(L,VL)	A(VL)	O(NO)	X(L,H)	A(L)	O(NO)	X(H)	V(H)									
Human-related Safety	X(VH,L)	X(VL,L)	X(H,L)	X(VH,H)	X(VL,H)	A(H)	O(NO)	X(VH,H)										
Worker-related Comfort	X(L)	X(L,VL)	X(L,VL)	X(L,VH)	X(L,H)	A(H)	O(NO)											
Property-related Security	A(L)	A(VL)	X(VL)	V(VL)	A(H)	A(H)												
Maintenance	X(L)	X(H,VH)	X(H,L)	X(H,VL)	X(H)													
Sustainability	X(VL,H)	X(H,VL)	X(H,L)	V(H)														
Time in Production	X(VH,L)	X(L,VH)	X(H,L)															
Time in non-Production	X(H)	X(H,VL)																
Production Characteristics	X(L)																	

Table 62: Pairwise Comparison of Expert 5

EXPERT 5	Other Characteristics	Production Characteristics	Time in non-Production	Time in Production	Sustainability	Maintenance	Property-related Security	Worker-related Comfort	Human-related Safety	Community Environment	Topography and Topology	Routing Flexibility	Volume Flexibility	Robustness	Non-Material Flow	Material Flow	Space Relationship	Inventory Cost
Non-Inventory Cost	X(L)	X(VH,H)	X(VH,H)	X(H)	X(H)	X(VH,H)	X(H)	X(VH,H)	X(VH,H)	X(H,VL)	X(H)	X(L,H)	X(L,H)	X(VL,L)	X(VH,H)	X(VH)	X(H)	X(H)
Inventory Cost	A(L)	X(L,H)	X(H)	A(VH)	A(H)	X(VL,H)	X(L,H)	X(VL,H)	O(NO)	A(VL)	A(H)	A(L)	X(VL,H)	A(H)	A(H)	O(NO)	A(VH)	
Space Relationship	X(L,H)	X(L,H)	X(H)	X(VH,H)	X(L)	X(L)	A(H)	X(L,H)	A(L)	X(L,H)	X(L,H)	X(H)	X(H)	X(VL,L)	X(H)	X(VH)		
Material Flow	X(L,H)	X(H)	X(H)	X(L,H)	X(H)	V(L)	A(H)	A(L)	X(H)	A(L)	X(L,H)	X(H,VH)	X(H,VH)	X(L,H)	X(H)			
Non-Material Flow	A(L)	X(H)	X(H)	X(VL,L)	X(H)	V(H)	X(H)	X(H)	X(L,H)	X(H)	X(H)	X(VH,L)	X(H)	X(L,VL)				
Robustness	V(VL)	X(H,L)	V(H)	X(H,L)	A(H)	X(H)	A(L)	A(VL)	X(L)	A(VL)	A(L)	A(L)	X(H)					
Volume Flexibility	X(L)	X(H)	X(VH,L)	X(H)	X(H)	X(H,L)	X(H,L)	X(H,L)	V(H)	O(NO)	X(L)	X(L,H)						
Routing Flexibility	V(H)	X(H)	X(H)	X(H)	X(H)	X(L)	A(H)	V(L)	X(L,H)	A(VL)	X(L)							
Topography and Topology	V(VL)	X(VL,L)	V(H)	V(VL)	X(L,H)	X(L)	X(H)	V(H)	X(H,L)	X(L,H)								
Community Environment	O(NO)	X(VL,L)	V(H)	V(H)	X(H)	A(L)	V(VL)	V(H)	X(H,L)									
Human-related Safety	X(H)	X(L,H)	X(H)	X(H)	X(L,H)	X(H,L)	V(H)	X(H)										
Worker-related Comfort	X(H)	X(H)	X(VH,H)	X(H)	X(L,H)	A(L)	O(NO)											
Property-related Security	A(L)	A(H)	X(L,H)	V(L)	A(H)	A(L)												
Maintenance	X(L,H)	X(H)	X(L)	X(H,L)	X(H)													
Sustainability	X(L,H)	X(H)	X(H,L)	V(H)														
Time in Production	X(L,H)	X(H)	X(H)															
Time in non-Production	X(H,L)	A(L)																
Production Characteristics	X(L,H)																	

Table 63: Pairwise Comparison of Expert 2

EXPERT 2	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	NO	H	H	VH	H	NO	H	L	VL	NO	L	L	L	H	H	H	H	VH	L
Inventory Cost	H	NO	H	L	NO	NO	L	NO	NO	NO	NO	NO	L	L	NO	L	L	NO	NO
Space Relationship	L	VH	NO	H	H	H	H	H	L	L	L	L	L	H	NO	VH	VH	H	L
Material Flow	VH	NO	VH	NO	H	L	H	H	L	NO	L	NO	NO	L	H	L	VH	H	L
Non-Material Flow	VH	NO	VH	H	NO	L	NO	L	L	NO	H	H	NO	NO	L	H	H	L	NO
Robustness	NO	VH	H	L	NO	NO	VH	VH	L	NO	L	L	NO	L	H	L	H	H	NO
Volume Flexibility	VH	H	H	VH	NO	H	NO	H	NO	NO	NO	NO	NO	L	H	L	VH	H	L
Routing Flexibility	VH	NO	H	VH	H	H	H	NO	L	NO	NO	NO	NO	NO	H	L	VH	H	NO
Topography and Topology	H	NO	H	H	H	NO	L	L	NO	NO	L	L	NO	NO	L	H	H	VL	NO
Community Environment	NO	NO	H	L	L	NO	L	L	NO	NO	H	H	NO	NO	L	NO	NO	L	NO
Human-related Safety	L	NO	L	H	H	L	L	L	L	H	NO	H	NO	NO	L	H	H	L	NO
Worker-related Comfort	L	NO	L	H	H	L	L	L	L	H	H	NO	NO	NO	L	L	L	L	L
Property-related Security	L	L	NO	H	L	L	L	H	L	H	H	H	NO	H	H	NO	H	L	L
Maintenance	H	H	L	NO	NO	L	L	L	L	L	H	H	H	NO	H	H	H	H	L
Sustainability	H	H	L	H	H	H	H	H	H	H	H	H	H	H	NO	H	H	H	L
Time in Production	VH	VH	H	H	H	L	H	H	NO	NO	NO	NO	NO	H	H	NO	H	H	H
Time in non-Production	VH	L	VH	VH	H	L	H	H	NO	NO	L	L	L	H	H	H	NO	L	H
Production Characteristics	H	H	H	H	H	L	H	H	L	L	H	H	H	H	VL	H	L	NO	L
Other Characteristics	H	L	H	H	H	L	NO	NO	H	H	L	L	L	L	H	L	H	L	NO

Table 64: Pairwise Comparison of Expert 3

EXPERT 3	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	NO	H	H	L	H	L	NO	VL	H	VH	H	L	L	L	H	VH	VH	L	L
Inventory Cost	L	NO	L	NO	NO	L	VH	NO	NO	NO	NO	NO	L	H	L	NO	NO	L	NO
Space Relationship	H	H	NO	VH	H	VL	H	H	H	H	NO	L	NO	L	L	H	H	L	L
Material Flow	VH	L	VH	NO	H	H	VH	VH	L	NO	NO	NO	NO	L	H	L	H	H	NO
Non-Material Flow	VH	H	VH	H	NO	L	L	VH	L	NO	NO	VL	NO	H	L	L	H	H	NO
Robustness	VL	VH	VL	H	VL	NO	H	VL	NO	NO	VL	NO	NO	H	NO	VH	VH	VH	L
Volume Flexibility	VH	H	VH	VH	VH	NO	NO	H	L	NO	NO	NO	L	NO	H	VH	VH	VH	L
Routing Flexibility	H	L	VH	VH	H	H	VH	NO	L	NO	L	L	NO	L	H	VH	VH	H	H
Topography and Topology	VH	NO	L	VH	VH	VL	L	L	NO	L	H	VH	H	H	L	VL	H	NO	NO
Community Environment	VL	VL	L	NO	NO	VL	NO	NO	L	NO	VH	VH	H	L	VH	H	L	VL	VL
Human-related Safety	L	NO	L	H	H	VL	NO	H	NO	NO	NO	H	NO	NO	L	H	H	L	H
Worker-related Comfort	L	L	L	L	L	NO	L	NO	VL	VL	H	NO	NO	NO	VL	H	H	H	H
Property-related Security	L	L	VL	VH	H	L	L	H	VH	VL	VL	VL	NO	VL	NO	L	L	NO	NO
Maintenance	H	H	NO	H	L	H	H	L	NO	NO	H	H	L	NO	H	H	H	H	L
Sustainability	H	VH	H	VH	H	L	L	H	H	H	H	H	H	L	NO	H	VH	H	H
Time in Production	VL	VH	H	VH	VL	L	H	H	NO	NO	H	H	NO	VL	NO	NO	H	L	VH
Time in non-Production	VH	H	H	H	H	L	L	H	NO	NO	H	L	H	H	L	H	NO	L	H
Production Characteristics	H	VH	H	VH	H	NO	L	L	L	L	H	H	NO	VH	VL	VH	VL	NO	L
Other Characteristics	VL	H	VH	L	H	NO	NO	NO	H	NO	L	H	L	H	H	L	L	L	NO

Table 65: Pairwise Comparison of Expert 4

EXPERT 4	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	NO	H	VH	VH	H	NO	H	VL	VL	NO	L	L	L	H	H	VH	VH	H	L
Inventory Cost	H	NO	VH	L	NO	NO	H	NO	NO	NO	NO	VL	L	H	NO	L	VL	L	NO
Space Relationship	L	VH	NO	H	H	H	H	H	L	H	L	L	L	H	NO	VH	VH	H	L
Material Flow	H	H	H	NO	H	H	H	H	H	H	H	L	H	H	H	H	H	H	L
Non-Material Flow	VH	NO	VH	H	NO	L	NO	L	L	NO	H	H	NO	NO	L	H	VH	L	NO
Robustness	VL	VH	VL	H	VL	NO	H	VL	NO	NO	VL	NO	NO	H	NO	VH	VH	VH	L
Volume Flexibility	H	H	VH	VH	VH	H	NO	L	L	NO	VH	H	H	H	H	VH	VH	VH	L
Routing Flexibility	L	L	VH	VH	H	L	VH	NO	L	NO	VH	H	H	H	H	VH	VH	VH	VH
Topography and Topology	H	NO	H	H	H	NO	L	L	NO	NO	L	L	NO	NO	L	H	H	L	NO
Community Environment	NO	NO	H	VL	VL	NO	VL	L	VL	NO	H	H	NO	NO	L	NO	NO	L	VL
Human-related Safety	H	VH	H	H	H	VL	L	VH	NO	NO	NO	VH	NO	NO	VL	H	H	VL	VH
Worker-related Comfort	L	NO	L	H	H	L	L	L	L	H	H	NO	NO	NO	L	L	L	L	L
Property-related Security	VH	H	VH	VH	H	L	L	VH	VH	NO	NO	NO	NO	NO	NO	VL	VL	NO	NO
Maintenance	H	H	L	NO	NO	L	L	L	L	L	H	H	H	NO	H	H	H	H	L
Sustainability	VH	VH	L	H	H	L	L	L	H	H	H	H	H	H	NO	H	H	H	VL
Time in Production	VL	VH	H	VH	VL	NO	VH	H	NO	NO	VH	VH	NO	VL	NO	NO	H	L	VH
Time in non-Production	VH	L	VH	H	H	L	H	H	VL	VL	L	VL	VL	L	L	L	NO	H	H
Production Characteristics	H	H	H	H	H	NO	L	L	VL	VL	L	VL	VL	VH	VL	VH	VL	NO	L
Other Characteristics	H	L	H	H	H	L	NO	NO	H	H	L	L	L	L	H	L	H	L	NO

Table 66: Pairwise Comparison of Expert 5

EXPERT 5	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	NO	H	H	VH	VH	VL	L	L	H	H	VH	VH	H	VH	H	H	VH	VH	L
Inventory Cost	H	NO	NO	NO	NO	NO	VL	NO	NO	NO	NO	VL	L	VL	NO	NO	H	L	NO
Space Relationship	H	VH	NO	VH	H	VL	H	H	L	L	NO	L	NO	L	L	VH	H	L	L
Material Flow	VH	NO	VH	NO	H	L	H	H	L	NO	H	NO	NO	L	H	L	H	H	L
Non-Material Flow	H	H	H	H	NO	L	H	VH	H	H	L	H	H	H	H	VL	H	H	NO
Robustness	L	H	L	H	VL	NO	H	L	NO	NO	L	NO	NO	H	NO	H	H	H	VL
Volume Flexibility	H	H	H	VH	H	H	NO	L	L	NO	H	H	H	H	H	H	VH	H	L
Routing Flexibility	H	L	H	VH	L	L	H	NO	L	NO	L	L	NO	L	H	H	H	H	H
Topography and Topology	H	H	H	H	H	L	L	L	NO	L	H	H	H	L	L	VL	H	VL	VL
Community Environment	VL	VL	H	L	H	VL	NO	VL	H	NO	H	H	VL	NO	H	H	H	VL	NO
Human-related Safety	H	NO	L	H	H	L	NO	H	L	L	NO	H	H	H	L	H	H	L	H
Worker-related Comfort	H	H	H	L	H	VL	L	NO	NO	NO	H	NO	NO	NO	L	H	VH	H	H
Property-related Security	H	H	H	H	H	L	L	H	H	NO	NO	NO	NO	NO	NO	L	L	NO	NO
Maintenance	H	H	L	NO	NO	H	L	L	L	L	L	L	L	NO	H	H	L	H	L
Sustainability	H	H	L	H	H	H	H	H	H	H	H	H	H	H	NO	H	H	H	L
Time in Production	H	VH	H	H	L	L	H	H	NO	NO	H	H	NO	L	NO	NO	H	H	L
Time in non-Production	H	H	H	H	H	NO	L	H	NO	NO	H	H	H	L	L	H	NO	NO	H
Production Characteristics	H	H	H	H	H	L	H	H	L	L	H	H	H	H	H	H	L	NO	L
Other Characteristics	L	L	H	H	L	NO	L	NO	NO	NO	H	H	L	H	H	H	L	H	NO

Table 67: Pairwise Comparison of Expert 2 with respect to Non-Inventory Cost

Non-Inventory Cost	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	SM	SM	MM	SM	SM	MM	MM	SM	SM	SM	SM	SM	SM	MM	MM	MM	MM	SM
Inventory Cost		E	E	E	MM	SM	E	E	SM	SM	MM	MM	MM	E	E	E	E	MM	SM
Space Relationship			E	E	E	MM	E	E	SM	SM	E	E	E	E	E	(MM)	(MM)	E	MM
Material Flow				E	MM	MM	MM	MM	SM	SM	MM	MM	MM	MM	MM	E	E	MM	MM
Non-Material Flow					E	MM	E	E	MM	MM	E	E	E	E	E	(MM)	E	E	MM
Robustness						E	(MM)	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	E
Volume Flexibility							E	MM	SM	MM	MM	MM	MM	MM	MM	E	E	MM	SM
Routing Flexibility								E	MM	MM	MM	MM	MM	E	E	E	E	E	MM
Topography and Topology									E	E	E	E	E	(MM)	E	(SM)	(MM)	(MM)	E
Community Environment										E	E	E	E	E	E	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	E	E	E	(MM)	(MM)	E	E
Worker-related Comfort												E	E	E	E	(MM)	(MM)	E	E
Property-related Security													E	E	(MM)	E	E	E	SM
Maintenance														E	E	(MM)	(MM)	(MM)	E
Sustainability															E	(MM)	(MM)	(MM)	E
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 68: Pairwise Comparison of Expert 2 with respect to Inventory Cost

Inventory Cost	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	(SM)	E	E	E	MM	E	E	MM	MM	E	E	E	E	E	E	E	E	E
Inventory Cost		E	MM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	MM	MM	MM	MM	MM	SM
Space Relationship			E	MM	MM	MM	MM	MM	MM	SM	MM	MM	MM	MM	MM	E	E	E	MM
Material Flow				E	E	MM	E	E	MM	SM	MM	MM	MM	MM	MM	E	E	E	MM
Non-Material Flow					E	E	E	E	MM	MM	MM	MM	MM	E	E	E	E	E	MM
Robustness						E	(MM)	(MM)	MM	MM	E	E	E	(MM)	E	(MM)	(MM)	(MM)	E
Volume Flexibility							E	MM	MM	MM	MM	MM	MM	E	E	(MM)	E	E	MM
Routing Flexibility								E	E	E	E	E	E	(MM)	E	(MM)	(MM)	(MM)	E
Topography and Topology									E	E	E	E	E	(SM)	(MM)	(SM)	(MM)	(MM)	E
Community Environment										E	(MM)	(MM)	(MM)	(SM)	(MM)	(SM)	(MM)	(MM)	E
Human-related Safety											E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Worker-related Comfort												E	E	(MM)	(MM)	(MM)	(MM)	E	MM
Property-related Security													E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Maintenance														E	MM	E	E	E	MM
Sustainability															E	(MM)	(MM)	(MM)	E
Time in Production																E	E	MM	MM
Time in non-Production																	E	E	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 69: Pairwise Comparison of Expert 2 with respect to Space Relationship

Space Relationship	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	(MM)	E	MM	MM	E	E	SM	SM	MM	MM	MM	E	MM	E	E	MM	SM
Inventory Cost		E	(SM)	(MM)	E	MM	E	E	MM	SM	MM	MM	MM	E	E	E	E	MM	SM
Space Relationship			E	MM	MM	SM	MM	MM	VSM	VSM	SM	SM	SM	MM	SM	MM	MM	SM	VSM
Material Flow				E	MM	MM	E	MM	SM	SM	MM	MM	MM	E	MM	E	E	MM	MM
Non-Material Flow					E	MM	E	E	MM	SM	MM	MM	MM	E	E	(MM)	(MM)	E	MM
Robustness						E	(MM)	(MM)	E	E	E	E	MM	(MM)	(MM)	(MM)	(MM)	(MM)	E
Volume Flexibility							E	MM	MM	MM	MM	MM	MM	E	MM	E	E	E	MM
Routing Flexibility								E	MM	MM	MM	E	MM	(MM)	E	(MM)	(MM)	(MM)	MM
Topography and Topology									E	E	E	E	E	(SM)	(MM)	(MM)	(MM)	(MM)	E
Community Environment										E	(MM)	(MM)	(MM)	(SM)	(MM)	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	E	(MM)	E	(MM)	(MM)	(MM)	E
Worker-related Comfort												E	MM	(MM)	E	(MM)	E	E	MM
Property-related Security													E	(MM)	E	(MM)	E	E	E
Maintenance														E	MM	E	E	E	MM
Sustainability															E	E	E	E	MM
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 70: Pairwise Comparison of Expert 2 with respect to Material Flow

Material Flow	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	SM	MM	(SM)	MM	SM	MM	MM	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Inventory Cost		E	(MM)	(SM)	E	MM	E	E	MM	MM	MM	MM	MM	E	E	E	E	E	MM
Space Relationship			E	(SM)	MM	MM	E	E	SM	SM	MM	MM	MM	E	E	E	E	E	MM
Material Flow				E	SM	SM	MM	MM	SM	SM	SM	SM	SM	MM	SM	MM	MM	MM	SM
Non-Material Flow					E	MM	E	E	MM	MM	E	MM	E	(MM)	E	(MM)	(MM)	(MM)	MM
Robustness						E	(MM)	(MM)	MM	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Volume Flexibility							E	E	MM	MM	MM	MM	MM	E	MM	E	E	E	MM
Routing Flexibility								E	MM	MM	E	E	E	(MM)	E	(MM)	(MM)	(MM)	E
Topography and Topology									E	E	(MM)	(MM)	(MM)	(SM)	(MM)	(MM)	(MM)	(MM)	E
Community Environment										E	(MM)	(MM)	(MM)	(SM)	(MM)	(MM)	(MM)	(MM)	(MM)
Human-related Safety											E	E	E	(MM)	E	(MM)	(MM)	E	MM
Worker-related Comfort												E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Property-related Security													E	(MM)	(MM)	(MM)	(MM)	E	E
Maintenance														E	MM	E	E	MM	MM
Sustainability															E	E	E	E	MM
Time in Production																E	E	MM	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 71: Pairwise Comparison of Expert 2 with respect to Non-Material Flow

Non-Material Flow	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	MM	(MM)	MM	MM	MM	SM	MM	SM	SM	SM	E	MM	MM	MM	MM	MM
Inventory Cost		E	(MM)	E	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	E	MM	E	E	E	MM
Space Relationship			E	E	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	E	MM	E	E	E	MM
Material Flow				E	(MM)	MM	E	E	MM	MM	E	E	MM	(MM)	E	(MM)	(MM)	E	MM
Non-Material Flow					E	SM	MM	MM	SM	SM	SM	SM	SM	MM	SM	MM	MM	SM	SM
Robustness						E	(MM)	E	MM	E	E	E	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Volume Flexibility							E	E	MM	MM	MM	MM	MM	E	MM	E	E	E	MM
Routing Flexibility								E	MM	MM	MM	MM	MM	(MM)	E	E	E	E	MM
Topography and Topology									E	E	E	E	E	(MM)	E	(MM)	(MM)	(MM)	E
Community Environment										E	(MM)	E	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Human-related Safety											E	MM	MM	(MM)	E	(MM)	(MM)	E	E
Worker-related Comfort												E	MM	(MM)	E	(MM)	(MM)	E	E
Property-related Security													E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Maintenance														E	MM	E	E	E	MM
Sustainability															E	E	E	E	MM
Time in Production																E	E	E	MM
Time in non-Production																	E	E	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 72: Pairwise Comparison of Expert 2 with respect to Robustness

Robustness	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	SM	(MM)	MM	MM	SM	SM	SM	SM	SM	MM	MM	MM	MM	MM	SM
Inventory Cost		E	E	E	MM	(MM)	MM	MM	SM	SM	SM	SM	SM	MM	MM	MM	MM	MM	SM
Space Relationship			E	E	E	(MM)	E	E	MM	SM	MM	MM	MM	E	E	E	(MM)	E	MM
Material Flow				E	MM	(MM)	E	MM	SM	SM	MM	MM	MM	E	E	E	E	E	MM
Non-Material Flow					E	(MM)	(MM)	E	MM	MM	MM	MM	MM	E	E	(MM)	(MM)	(MM)	E
Robustness						E	MM	MM	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Volume Flexibility							E	MM	SM	SM	MM	SM	MM	E	E	E	E	E	MM
Routing Flexibility								E	MM	MM	MM	MM	MM	E	E	E	E	E	E
Topography and Topology									E	E	E	E	E	(MM)	E	(MM)	(MM)	(MM)	E
Community Environment										E	E	E	E	(MM)	E	E	E	E	MM
Human-related Safety											E	E	E	E	E	E	E	E	E
Worker-related Comfort												E	E	(MM)	E	(MM)	(MM)	(MM)	E
Property-related Security													E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Maintenance														E	MM	E	E	E	MM
Sustainability															E	(MM)	(MM)	E	E
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 73: Pairwise Comparison of Expert 2 with respect to Volume Flexibility

Volume Flexibility	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	MM	SM	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Inventory Cost		E	E	E	E	MM	(MM)	E	MM	MM	MM	MM	MM	MM	MM	E	E	MM	MM
Space Relationship			E	E	MM	MM	(SM)	E	MM	SM	MM	MM	MM	E	MM	E	E	E	MM
Material Flow				E	MM	MM	(MM)	E	SM	SM	MM	MM	MM	MM	E	E	E	E	MM
Non-Material Flow					E	MM	(SM)	E	MM	MM	E	E	MM	E	E	(MM)	(MM)	(MM)	MM
Robustness						E	(SM)	E	MM	MM	(MM)	E	E	(MM)	E	(MM)	(MM)	(MM)	MM
Volume Flexibility							E	MM	VSM	VSM	MM	MM	MM	MM	SM	MM	MM	MM	SM
Routing Flexibility								E	MM	MM	E	E	E	(MM)	E	(MM)	(MM)	(MM)	E
Topography and Topology									E	E	(MM)	(MM)	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Community Environment										E	(MM)	(MM)	E	(MM)	(MM)	(MM)	(MM)	(MM)	MM
Human-related Safety											E	MM	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	E	(MM)	E	(MM)	(MM)	E	E
Property-related Security													E	(MM)	E	(MM)	(MM)	(MM)	E
Maintenance														E	MM	E	E	E	MM
Sustainability															E	E	E	E	E
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 74: Pairwise Comparison of Expert 2 with respect to Routing Flexibility

Routing Flexibility	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	MM	MM	MM	(MM)	SM	SM	MM	MM	MM	MM	MM	MM	E	MM	SM
Inventory Cost		E	E	E	E	MM	E	(MM)	SM	SM	MM	MM	MM	E	MM	E	E	E	MM
Space Relationship			E	E	MM	MM	E	(MM)	SM	SM	MM	MM	MM	E	E	E	E	E	E
Material Flow				E	MM	MM	MM	(MM)	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Non-Material Flow					E	MM	E	(MM)	MM	SM	MM	MM	MM	E	MM	E	E	E	E
Robustness						E	(MM)	(SM)	MM	MM	E	E	E	(MM)	E	(MM)	(MM)	(MM)	E
Volume Flexibility							E	(MM)	MM	MM	MM	MM	MM	E	E	E	E	E	MM
Routing Flexibility								E	SM	SM	SM	SM	SM	MM	MM	MM	MM	MM	SM
Topography and Topology									E	E	E	E	E	(MM)	E	(MM)	(MM)	(MM)	E
Community Environment										E	E	E	E	(MM)	E	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	E	(MM)	(MM)	(MM)	(MM)	E	E
Worker-related Comfort												E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Property-related Security													E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Maintenance														E	MM	E	E	E	MM
Sustainability															E	(MM)	(MM)	E	MM
Time in Production																E	E	MM	MM
Time in non-Production																	E	MM	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 75: Pairwise Comparison of Expert 2 with respect to Topography and

Topography and Topology	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	MM	SM	MM	MM	(MM)	SM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Inventory Cost		E	E	E	MM	MM	MM	MM	(MM)	MM	MM	MM	MM	E	E	E	E	E	MM
Space Relationship			E	E	MM	MM	E	MM	(MM)	MM	MM	MM	MM	E	MM	E	E	MM	E
Material Flow				E	MM	MM	E	E	(MM)	SM	MM	MM	SM	E	MM	E	E	E	E
Non-Material Flow					E	E	(MM)	E	(MM)	MM	E	MM	MM	(MM)	E	(MM)	(MM)	E	E
Robustness						E	(MM)	E	(SM)	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Volume Flexibility							E	MM	(MM)	SM	MM	MM	MM	E	MM	E	E	E	E
Routing Flexibility								E	(MM)	MM	E	E	E	(MM)	E	(MM)	(MM)	E	(MM)
Topography and Topology									E	SM	SM	SM	SM	MM	SM	MM	MM	MM	MM
Community Environment										E	(MM)	E	E	(MM)	E	(MM)	(MM)	E	(MM)
Human-related Safety											E	MM	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	E	(MM)	E	(MM)	(MM)	E	(MM)
Property-related Security													E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Maintenance														E	MM	E	E	E	(MM)
Sustainability															E	E	E	E	(MM)
Time in Production																E	E	MM	E
Time in non-Production																	E	MM	E
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 76: Pairwise Comparison of Expert 2 with respect to Community Environment

Community Environment	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	MM	MM	MM	MM	SM	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	MM
Inventory Cost		E	(MM)	E	(MM)	MM	MM	MM	MM	(MM)	MM	MM	MM	E	MM	E	E	E	E
Space Relationship			E	E	MM	SM	E	MM	MM	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	MM
Material Flow				E	MM	MM	MM	MM	MM	(MM)	MM	MM	MM	E	MM	E	E	MM	E
Non-Material Flow					E	E	(MM)	E	MM	(MM)	MM	MM	MM	E	E	E	E	E	(MM)
Robustness						E	(MM)	E	MM	(SM)	E	E	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Volume Flexibility							E	MM	SM	(MM)	MM	MM	MM	MM	SM	MM	MM	MM	E
Routing Flexibility								E	MM	(MM)	E	E	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Topography and Topology									E	(MM)	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(SM)
Community Environment										E	SM	SM	SM	MM	SM	MM	MM	SM	MM
Human-related Safety											E	E	E	(MM)	E	E	E	E	(MM)
Worker-related Comfort												E	E	(MM)	E	(MM)	(MM)	E	(MM)
Property-related Security													E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Maintenance														E	MM	E	E	E	(MM)
Sustainability															E	(MM)	(MM)	E	(MM)
Time in Production																E	E	MM	(MM)
Time in non-Production																	E	MM	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 77: Pairwise Comparison of Expert 2 with respect to Human-related Safety

Human-related Safety	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	E	SM	MM	SM	SM	SM	(MM)	SM	SM	MM	SM	MM	MM	MM	SM
Inventory Cost		E	E	E	(MM)	MM	E	MM	MM	SM	(SM)	MM	MM	E	MM	E	E	MM	MM
Space Relationship			E	E	(MM)	MM	E	MM	MM	MM	(MM)	MM	MM	E	MM	E	E	MM	MM
Material Flow				E	(MM)	MM	E	MM	MM	MM	(MM)	MM	MM	MM	MM	MM	MM	MM	SM
Non-Material Flow					E	SM	MM	SM	SM	SM	(MM)	MM	MM	MM	MM	MM	MM	MM	SM
Robustness						E	(MM)	E	MM	MM	(SM)	MM	MM	E	E	E	(MM)	(MM)	E
Volume Flexibility							E	MM	MM	MM	(MM)	MM	MM	MM	MM	MM	E	MM	MM
Routing Flexibility								E	MM	MM	(MM)	MM	MM	MM	MM	MM	E	E	MM
Topography and Topology									E	MM	(SM)	E	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Community Environment										E	(SM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Human-related Safety											E	SM	SM	SM	SM	MM	MM	MM	SM
Worker-related Comfort												E	E	(MM)	E	(MM)	(MM)	(MM)	MM
Property-related Security													E	(MM)	E	(MM)	(MM)	(MM)	E
Maintenance														E	E	E	E	E	MM
Sustainability															E	E	E	E	E
Time in Production																E	E	MM	MM
Time in non-Production																	E	MM	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 78: Pairwise Comparison of Expert 2 with respect Worker-related Comfort

Worker-related Comfort	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	MM	(MM)	SM	MM	MM	SM	SM	MM	(SM)	MM	MM	SM	MM	MM	MM	MM
Inventory Cost		E	(MM)	E	(MM)	MM	MM	MM	SM	SM	MM	(SM)	MM	MM	MM	MM	MM	MM	MM
Space Relationship			E	E	(MM)	MM	MM	MM	SM	SM	MM	(SM)	MM	MM	MM	MM	MM	MM	MM
Material Flow				E	(MM)	MM	MM	MM	SM	SM	MM	(SM)	MM	MM	MM	MM	MM	MM	MM
Non-Material Flow					E	MM	MM	MM	SM	SM	MM	(MM)	MM	MM	SM	MM	MM	MM	SM
Robustness						E	(MM)	E	MM	MM	MM	(SM)	MM	(MM)	MM	E	E	E	MM
Volume Flexibility							E	MM	SM	SM	MM	(MM)	SM	MM	MM	MM	MM	MM	SM
Routing Flexibility								E	SM	MM	E	(SM)	E	E	MM	E	E	E	MM
Topography and Topology									E	E	(MM)	(SM)	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Community Environment										E	E	(SM)	E	(MM)	E	(MM)	E	E	E
Human-related Safety											E	(MM)	MM	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	VSM	MM	SM	MM	MM	SM	SM
Property-related Security													E	(MM)	E	(MM)	(MM)	E	MM
Maintenance														E	MM	E	E	E	MM
Sustainability															E	E	E	MM	MM
Time in Production																E	E	MM	MM
Time in non-Production																	E	MM	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 79: Pairwise Comparison of Expert 2 with respect Property-related Security

Property-related Security	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	MM	SM	MM	SM	SM	SM	MM	MM	(MM)	MM	MM	MM	MM	MM	SM
Inventory Cost		E	(MM)	(MM)	E	MM	E	MM	MM	MM	MM	MM	(MM)	E	E	E	E	E	MM
Space Relationship			E	E	MM	SM	MM	SM	SM	SM	MM	MM	(MM)	MM	MM	MM	MM	MM	MM
Material Flow				E	MM	MM	MM	MM	SM	SM	MM	MM	(MM)	MM	MM	MM	MM	MM	MM
Non-Material Flow					E	MM	E	MM	MM	MM	E	E	(MM)	(MM)	E	(MM)	(MM)	E	E
Robustness						E	(MM)	E	MM	MM	E	E	(SM)	(MM)	(MM)	(MM)	(MM)	(MM)	E
Volume Flexibility							E	MM	SM	SM	MM	MM	(MM)	E	MM	E	E	MM	MM
Routing Flexibility								E	MM	MM	MM	MM	(MM)	E	MM	E	E	MM	MM
Topography and Topology									E	E	E	E	(SM)	E	E	E	E	E	E
Community Environment										E	E	E	(SM)	(MM)	(MM)	E	E	E	E
Human-related Safety											E	MM	(SM)	(MM)	E	(MM)	(MM)	E	E
Worker-related Comfort												E	(SM)	(MM)	E	(MM)	(MM)	E	E
Property-related Security													E	MM	SM	MM	MM	MM	SM
Maintenance														E	MM	E	E	E	MM
Sustainability															E	E	E	E	MM
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 80: Pairwise Comparison of Expert 2 with respect Maintenance

Maintenance	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	E	SM	MM	SM	SM	SM	SM	SM	MM	(MM)	MM	MM	MM	MM	MM
Inventory Cost		E	(MM)	(MM)	E	MM	MM	MM	MM	MM	MM	MM	E	(MM)	MM	E	E	MM	MM
Space Relationship			E	MM	MM	SM	MM	SM	SM	SM	SM	SM	MM	(MM)	MM	MM	MM	MM	SM
Material Flow				E	E	MM	MM	MM	MM	MM	MM	MM	E	(MM)	MM	E	E	MM	MM
Non-Material Flow					E	E	E	MM	MM	MM	MM	MM	E	(MM)	MM	E	E	MM	MM
Robustness						E	E	MM	MM	MM	MM	MM	E	(MM)	MM	E	E	E	MM
Volume Flexibility							E	E	MM	MM	MM	MM	E	(MM)	MM	E	E	E	MM
Routing Flexibility								E	MM	MM	E	E	(MM)	(SM)	MM	E	E	E	MM
Topography and Topology									E	E	E	E	(MM)	(SM)	MM	E	E	E	MM
Community Environment										E	(MM)	(MM)	(SM)	(VSM)	E	E	E	E	MM
Human-related Safety											E	MM	(MM)	(SM)	E	E	E	E	MM
Worker-related Comfort												E	(MM)	(SM)	E	E	E	E	E
Property-related Security													E	(MM)	MM	E	E	E	MM
Maintenance														E	MM	SM	VSM	SM	VSM
Sustainability															E	(MM)	E	(MM)	E
Time in Production																E	E	MM	MM
Time in non-Production																	E	MM	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 81: Pairwise Comparison of Expert 2 with respect Sustainability

Sustainability	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	SM	SM	SM	SM	SM	SM	SM	MM	MM	MM	MM	(MM)	MM	MM	MM	MM
Inventory Cost		E	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	(MM)	MM	MM	E	MM
Space Relationship			E	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	(MM)	MM	MM	MM	MM
Material Flow				E	E	MM	MM	MM	MM	MM	E	E	E	E	(MM)	E	E	E	MM
Non-Material Flow					E	E	E	E	MM	MM	MM	MM	MM	E	(MM)	E	E	E	MM
Robustness						E	(MM)	E	MM	MM	MM	MM	MM	E	(MM)	(MM)	(MM)	(MM)	MM
Volume Flexibility							E	E	MM	MM	E	E	E	E	(SM)	E	E	E	MM
Routing Flexibility								E	MM	MM	E	E	E	(MM)	(SM)	(MM)	(MM)	(MM)	E
Topography and Topology									E	E	(MM)	(MM)	(MM)	(MM)	(SM)	(MM)	(MM)	(MM)	E
Community Environment										E	(MM)	E	(MM)	(MM)	(SM)	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	(MM)	(MM)	(SM)	(MM)	(MM)	(MM)	E
Worker-related Comfort												E	E	(MM)	(SM)	(MM)	(MM)	(MM)	E
Property-related Security													E	(MM)	(SM)	(MM)	(MM)	(MM)	E
Maintenance														E	(MM)	E	E	E	MM
Sustainability															E	SM	SM	SM	VSM
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 82: Pairwise Comparison of Expert 2 with respect Time in Production

Time in Production	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	MM	E	MM	(MM)	MM	(SM)	(MM)	E	E
Inventory Cost		E	E	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	MM	E	MM	(MM)	E	(SM)	(MM)	E	E
Space Relationship			E	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	MM	E	MM	(MM)	MM	(MM)	(MM)	E	E
Material Flow				E	E	SM	E	E	SM	SM	SM	MM	SM	E	MM	(MM)	E	MM	MM
Non-Material Flow					E	SM	E	E	SM	SM	SM	MM	SM	E	MM	(MM)	E	MM	MM
Robustness						E	(MM)	(MM)	MM	MM	MM	E	E	E	E	(SM)	(MM)	(MM)	(MM)
Volume Flexibility							E	E	SM	SM	MM	E	MM	E	MM	(MM)	E	E	E
Routing Flexibility								E	SM	SM	MM	E	MM	E	MM	(MM)	E	E	E
Topography and Topology									E	E	E	(MM)	E	(MM)	E	(SM)	(MM)	(MM)	(MM)
Community Environment										E	E	(MM)	E	(MM)	E	(SM)	(MM)	(MM)	E
Human-related Safety											E	(MM)	E	(MM)	E	(SM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	MM	E	MM	(MM)	E	E	E
Property-related Security													E	(MM)	E	(SM)	(MM)	(MM)	(MM)
Maintenance														E	MM	(MM)	E	E	E
Sustainability															E	(SM)	(MM)	E	E
Time in Production																E	MM	SM	SM
Time in non-Production																	E	MM	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 83: Pairwise Comparison of Expert 2 with respect Time in Non-Production

Time in non-Production	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	MM	E	MM	(MM)	MM	(MM)	(SM)	E	E
Inventory Cost		E	(MM)	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	MM	(MM)	MM	(MM)	E	(MM)	(SM)	E	E
Space Relationship			E	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	MM	E	MM	(MM)	MM	(MM)	(SM)	E	E
Material Flow				E	E	SM	E	E	SM	SM	SM	MM	SM	E	MM	E	(MM)	MM	MM
Non-Material Flow					E	SM	E	E	SM	SM	SM	MM	SM	E	MM	E	(MM)	MM	MM
Robustness						E	(MM)	(MM)	MM	MM	MM	E	E	E	E	(MM)	(SM)	(MM)	(MM)
Volume Flexibility							E	E	SM	SM	MM	E	MM	E	MM	E	(MM)	E	E
Routing Flexibility								E	SM	SM	MM	E	MM	E	MM	E	(MM)	E	E
Topography and Topology									E	E	E	(MM)	E	(MM)	E	(MM)	(SM)	(MM)	(MM)
Community Environment										E	E	(MM)	E	(MM)	E	(MM)	(SM)	(MM)	E
Human-related Safety											E	(MM)	E	(MM)	E	(MM)	(SM)	(MM)	(MM)
Worker-related Comfort												E	MM	E	MM	E	(MM)	E	E
Property-related Security													E	(MM)	E	(MM)	(SM)	(MM)	(MM)
Maintenance														E	MM	E	(MM)	E	E
Sustainability															E	(MM)	(SM)	E	E
Time in Production																E	(MM)	MM	MM
Time in non-Production																	E	SM	SM
Production Characteristics																		E	E
Other Characteristics																			E

Table 84: Pairwise Comparison of Expert 2 with respect Production Characteristics

Production Characteristics	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	E	SM	E	MM	SM	SM	MM	MM	MM	MM	MM	E	E	(MM)	E
Inventory Cost		E	E	E	E	SM	E	E	SM	SM	MM	MM	MM	MM	MM	E	E	(MM)	E
Space Relationship			E	E	E	SM	E	E	SM	SM	MM	MM	MM	MM	MM	E	E	(MM)	E
Material Flow				E	E	SM	E	MM	SM	SM	MM	MM	MM	MM	MM	E	E	(MM)	E
Non-Material Flow					E	MM	E	E	SM	MM	MM	MM	MM	MM	MM	E	E	(MM)	E
Robustness						E	(MM)	(MM)	MM	MM	MM	MM	MM	E	MM	(MM)	(MM)	(SM)	(MM)
Volume Flexibility							E	E	MM	MM	MM	MM	MM	E	MM	E	E	(MM)	E
Routing Flexibility								E	MM	MM	MM	MM	MM	E	MM	E	E	(MM)	E
Topography and Topology									E	MM	E	E	E	(MM)	E	(MM)	(MM)	(SM)	(MM)
Community Environment										E	(MM)	(MM)	E	(MM)	E	(MM)	(MM)	(SM)	(MM)
Human-related Safety											E	(MM)	E	(MM)	E	(MM)	(MM)	(SM)	(MM)
Worker-related Comfort												E	MM	(MM)	E	(MM)	(MM)	(SM)	(MM)
Property-related Security													E	(MM)	E	(MM)	(MM)	(SM)	(MM)
Maintenance														E	MM	E	E	(MM)	E
Sustainability															E	(MM)	(MM)	(SM)	(MM)
Time in Production																E	E	(MM)	E
Time in non-Production																	E	(MM)	E
Production Characteristics																		E	SM
Other Characteristics																			E

Table 85: Pairwise Comparison of Expert 2 with respect Other Characteristics

Other Characteristics	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	MM	SM	MM	MM	SM	SM	MM	MM	MM	MM	MM	MM	MM	E	(MM)
Inventory Cost		E	E	E	E	SM	E	E	SM	SM	MM	MM	MM	MM	MM	E	E	E	(MM)
Space Relationship			E	E	E	SM	E	E	SM	SM	MM	MM	MM	MM	MM	E	E	E	(MM)
Material Flow				E	E	SM	E	MM	SM	SM	MM	MM	MM	MM	MM	E	E	E	(MM)
Non-Material Flow					E	MM	E	E	SM	MM	MM	MM	MM	MM	MM	E	E	E	(MM)
Robustness						E	(MM)	(MM)	MM	MM	MM	MM	MM	E	MM	(MM)	(MM)	(MM)	(SM)
Volume Flexibility							E	E	MM	MM	MM	MM	MM	E	MM	E	E	E	(MM)
Routing Flexibility								E	MM	MM	MM	MM	MM	E	MM	E	E	E	(MM)
Topography and Topology									E	MM	E	E	E	(MM)	E	(MM)	(MM)	(MM)	(SM)
Community Environment										E	(MM)	(MM)	E	(MM)	E	(MM)	(MM)	(MM)	(SM)
Human-related Safety											E	(MM)	E	(MM)	E	(MM)	(MM)	(MM)	(SM)
Worker-related Comfort												E	MM	(MM)	E	(MM)	(MM)	(MM)	(SM)
Property-related Security													E	(MM)	E	(MM)	(MM)	(MM)	(SM)
Maintenance														E	MM	E	E	E	(MM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(SM)
Other Characteristics																			E

Table 86: Pairwise Comparison of Expert 3 with respect to Non-Inventory Cost

Non-Inventory Cost	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	SM	SM	SM	SM	VSM	MM	MM	VSM	VSM	SM	SM	SM	SM	SM	MM	MM	SM	VSM
Inventory Cost		E	E	E	E	MM	E	E	MM	MM	MM	MM	MM	MM	MM	E	E	MM	MM
Space Relationship			E	E	MM	SM	E	E	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Material Flow				E	MM	SM	E	E	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Non-Material Flow					E	MM	(MM)	E	MM	MM	MM	MM	MM	(MM)	E	(MM)	E	MM	MM
Robustness						E	(MM)	E	MM	MM	MM	MM	MM	(MM)	E	(MM)	(MM)	(MM)	(MM)
Volume Flexibility							E	MM	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Routing Flexibility								E	SM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Topography and Topology									E	E	E	E	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Community Environment										E	(MM)	(MM)	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	MM	(MM)	E	(MM)	(MM)	E	E
Worker-related Comfort												E	MM	(MM)	E	(MM)	(MM)	E	E
Property-related Security													E	(MM)	E	(MM)	(MM)	(MM)	MM
Maintenance														E	MM	E	E	E	MM
Sustainability															E	E	(MM)	(MM)	E
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 87: Pairwise Comparison of Expert 3 with respect to Inventory Cost

Inventory Cost	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	(MM)	MM	MM	MM	SM	MM	MM	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Inventory Cost		E	SM	SM	SM	SM	MM	SM	VSM	VSM	SM	SM	SM	MM	SM	MM	MM	MM	SM
Space Relationship			E	(MM)	E	MM	(MM)	E	SM	SM	MM	MM	MM	MM	MM	E	E	E	MM
Material Flow				E	MM	MM	E	MM	SM	SM	MM	MM	MM	MM	MM	E	E	E	MM
Non-Material Flow					E	E	(MM)	E	MM	MM	MM	MM	MM	(MM)	E	(MM)	E	E	MM
Robustness						E	(MM)	E	SM	SM	MM	MM	MM	(MM)	E	(MM)	(MM)	(MM)	E
Volume Flexibility							E	MM	SM	SM	MM	MM	MM	E	E	E	E	E	MM
Routing Flexibility								E	MM	MM	MM	MM	MM	E	E	E	E	E	MM
Topography and Topology									E	E	E	E	E	E	E	E	E	E	MM
Community Environment										E	E	E	E	(MM)	E	E	E	E	MM
Human-related Safety											E	E	E	(MM)	E	(MM)	(MM)	E	MM
Worker-related Comfort												E	E	(MM)	E	(MM)	(MM)	E	MM
Property-related Security													E	(MM)	E	(MM)	(MM)	E	MM
Maintenance														E	MM	E	E	E	MM
Sustainability															E	E	E	E	MM
Time in Production																E	E	MM	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 88: Pairwise Comparison of Expert 3 with respect to Space Relationship

Space Relationship	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	(MM)	MM	MM	SM	MM	SM	VSM	VSM	SM	SM	SM	MM	SM	MM	MM	MM	SM
Inventory Cost		E	(MM)	MM	MM	MM	E	MM	SM	SM	MM	MM	MM	MM	MM	E	E	MM	SM
Space Relationship			E	MM	MM	SM	MM	SM	VSM	VSM	SM	SM	SM	MM	SM	MM	MM	SM	VSM
Material Flow				E	E	MM	E	MM	SM	SM	MM	MM	MM	MM	SM	E	E	MM	SM
Non-Material Flow					E	MM	E	MM	SM	SM	MM	MM	MM	MM	SM	E	E	MM	MM
Robustness						E	(MM)	E	MM	MM	MM	MM	MM	E	MM	E	E	E	MM
Volume Flexibility							E	MM	SM	SM	MM	MM	MM	MM	MM	E	E	MM	SM
Routing Flexibility								E	MM	MM	MM	MM	MM	E	MM	(MM)	E	MM	MM
Topography and Topology									E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	E
Community Environment										E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	MM	(MM)	E	(MM)	(MM)	E	MM
Worker-related Comfort												E	MM	(MM)	E	(MM)	(MM)	E	MM
Property-related Security													E	(MM)	E	(MM)	(MM)	E	E
Maintenance														E	MM	E	E	E	MM
Sustainability															E	E	E	E	MM
Time in Production																E	E	MM	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 89: Pairwise Comparison of Expert 3 with respect to Material Flow

Material Flow	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	(SM)	MM	SM	MM	SM	VSM	VSM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Inventory Cost		E	(MM)	(SM)	E	MM	E	MM	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Space Relationship			E	(MM)	MM	SM	MM	SM	VSM	VSM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Material Flow				E	SM	SM	MM	SM	EM	EM	VSM	VSM	VSM	SM	SM	SM	SM	MM	SM
Non-Material Flow					E	MM	(MM)	E	SM	SM	MM	MM	MM	MM	MM	E	E	MM	MM
Robustness						E	(MM)	E	MM	MM	E	E	E	(MM)	E	(MM)	(MM)	E	E
Volume Flexibility							E	MM	SM	SM	SM	SM	SM	MM	SM	MM	MM	MM	SM
Routing Flexibility								E	MM	MM	E	MM	MM	E	MM	E	E	E	MM
Topography and Topology									E	E	(MM)	(MM)	(MM)	(MM)	E	(MM)	(MM)	(MM)	E
Community Environment										E	(MM)	(MM)	(MM)	(MM)	E	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	E	(MM)	(SM)	(MM)	(MM)	(MM)	E
Worker-related Comfort												E	E	E	E	(MM)	(MM)	E	E
Property-related Security													E	(MM)	E	(MM)	(MM)	E	E
Maintenance														E	E	(MM)	(MM)	(MM)	E
Sustainability															E	(MM)	(MM)	(MM)	E
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 90: Pairwise Comparison of Expert 3 with respect to Non-Material Flow

Non-Material Flow	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	MM	(MM)	SM	MM	MM	SM	SM	MM	MM	SM	MM	SM	MM	MM	MM	MM
Inventory Cost		E	(MM)	E	(SM)	MM	E	MM	MM	MM	MM	MM	SM	MM	MM	MM	MM	MM	MM
Space Relationship			E	MM	(MM)	SM	MM	MM	SM	SM	MM	MM	SM	MM	SM	MM	MM	MM	MM
Material Flow				E	(SM)	MM	E	MM	MM	MM	MM	MM	MM	MM	MM	E	E	E	MM
Non-Material Flow					E	SM	MM	SM	VSM	SM	SM	SM	SM	SM	SM	MM	MM	SM	SM
Robustness						E	(MM)	E	MM	MM	E	E	MM	E	MM	E	E	E	E
Volume Flexibility							E	MM	SM	SM	MM	MM	MM	MM	MM	E	E	E	MM
Routing Flexibility								E	MM	MM	MM	MM	MM	E	MM	E	E	E	MM
Topography and Topology									E	E	(MM)	(MM)	(MM)	(MM)	E	(MM)	(MM)	(MM)	E
Community Environment										E	(MM)	(MM)	(MM)	(MM)	E	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Worker-related Comfort												E	E	(MM)	E	(MM)	(MM)	(MM)	MM
Property-related Security													E	(MM)	E	(MM)	(MM)	(MM)	E
Maintenance														E	MM	E	E	MM	MM
Sustainability															E	E	E	E	MM
Time in Production																E	MM	MM	MM
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 91: Pairwise Comparison of Expert 3 with respect to Robustness

Robustness	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	(MM)	E	E	E	(SM)	E	MM	SM	SM	MM	MM	MM	MM	MM	(MM)	(MM)	E	MM
Inventory Cost		E	MM	MM	MM	(MM)	MM	SM	VSM	VSM	MM	MM	SM	MM	MM	(MM)	(MM)	MM	MM
Space Relationship			E	E	E	(SM)	E	MM	SM	SM	MM	MM	SM	MM	MM	(MM)	(MM)	(MM)	E
Material Flow				E	E	(SM)	E	MM	SM	SM	MM	SM	SM	MM	MM	(MM)	(MM)	E	E
Non-Material Flow					E	(SM)	E	MM	SM	SM	MM	MM	MM	MM	MM	(MM)	(MM)	E	E
Robustness						E	MM	SM	VSM	VSM	SM	SM	SM	MM	MM	MM	MM	MM	SM
Volume Flexibility							E	MM	SM	SM	MM	SM	MM	MM	MM	E	E	MM	MM
Routing Flexibility								E	MM	MM	MM	MM	MM	MM	MM	E	E	E	E
Topography and Topology									E	E	MM	MM	MM	E	MM	(MM)	(MM)	(MM)	E
Community Environment										E	MM	MM	MM	E	MM	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	E	E	E	(MM)	(MM)	MM	MM
Worker-related Comfort												E	E	E	E	(MM)	(MM)	E	E
Property-related Security													E	E	E	(MM)	(MM)	E	E
Maintenance														E	E	E	E	E	MM
Sustainability															E	E	E	E	MM
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 92: Pairwise Comparison of Expert 3 with respect to Volume Flexibility

Volume Flexibility	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	SM	SM	(MM)	SM	VSM	VSM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Inventory Cost		E	(MM)	(MM)	MM	MM	(SM)	MM	SM	SM	MM	MM	MM	MM	MM	E	E	MM	MM
Space Relationship			E	E	SM	SM	(MM)	SM	VSM	VSM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Material Flow				E	SM	SM	(MM)	SM	VSM	VSM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Non-Material Flow					E	E	(SM)	E	MM	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	E	E
Robustness						E	(SM)	E	MM	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	E	E
Volume Flexibility							E	SM	VSM	VSM	SM	SM	SM	SM	SM	MM	MM	MM	SM
Routing Flexibility								E	MM	MM	E	E	MM	E	E	E	E	E	MM
Topography and Topology									E	E	(MM)	(MM)	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Community Environment										E	(MM)	(MM)	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Property-related Security													E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Maintenance														E	E	E	E	E	E
Sustainability															E	E	E	E	E
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 93: Pairwise Comparison of Expert 3 with respect to Routing Flexibility

Routing Flexibility	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	SM	SM	MM	(MM)	VSM	VSM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Inventory Cost		E	(MM)	(MM)	MM	MM	MM	(MM)	SM	SM	MM	MM	MM	MM	MM	E	E	MM	MM
Space Relationship			E	E	SM	SM	MM	(MM)	VSM	VSM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Material Flow				E	SM	SM	MM	(MM)	VSM	VSM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Non-Material Flow					E	E	E	(SM)	MM	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	E	E
Robustness						E	(MM)	(SM)	MM	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	E	E
Volume Flexibility							E	(MM)	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Routing Flexibility								E	SM	SM	SM	SM	SM	MM	SM	MM	MM	MM	MM
Topography and Topology									E	E	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Community Environment										E	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Property-related Security													E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Maintenance														E	E	E	E	E	E
Sustainability															E	E	E	E	E
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 94: Pairwise Comparison of Expert 3 with respect to Topography and Topology

Topography and Topology	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	MM	SM	MM	SM	(MM)	SM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Inventory Cost		E	(MM)	(MM)	E	MM	E	MM	(MM)	MM	MM	MM	MM	MM	MM	E	E	E	E
Space Relationship			E	E	MM	SM	MM	SM	(MM)	SM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Material Flow				E	MM	SM	MM	SM	(MM)	SM	MM	MM	MM	MM	E	MM	MM	MM	MM
Non-Material Flow					E	MM	E	MM	(SM)	MM	MM	MM	MM	MM	MM	E	E	E	E
Robustness						E	(MM)	E	(SM)	MM	E	E	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Volume Flexibility							E	MM	(MM)	SM	MM	MM	MM	MM	MM	E	E	E	(MM)
Routing Flexibility								E	(MM)	MM	MM	MM	MM	E	MM	(MM)	(MM)	(MM)	(MM)
Topography and Topology									E	SM	SM	SM	SM	MM	SM	MM	MM	MM	MM
Community Environment										E	E	E	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Human-related Safety											E	E	E	E	E	(MM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	E	E	E	(MM)	(MM)	(MM)	(MM)
Property-related Security													E	E	E	(MM)	(MM)	(MM)	(MM)
Maintenance														E	E	E	E	E	E
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	(MM)	(MM)
Time in non-Production																	E	(MM)	(MM)
Production Characteristics																		E	E
Other Characteristics																			E

Table 95: Pairwise Comparison of Expert 3 with respect to Community Environment

Community Environment	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	MM	SM	MM	SM	SM	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	MM
Inventory Cost		E	(MM)	(MM)	E	MM	E	MM	MM	(MM)	MM	MM	MM	MM	MM	E	E	E	E
Space Relationship			E	E	MM	SM	MM	SM	SM	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	MM
Material Flow				E	MM	SM	MM	SM	SM	(MM)	MM	MM	MM	MM	E	MM	MM	MM	MM
Non-Material Flow					E	MM	E	MM	MM	(SM)	MM	MM	MM	MM	MM	E	E	E	E
Robustness						E	(MM)	E	MM	(SM)	E	E	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Volume Flexibility							E	MM	SM	(MM)	MM	MM	MM	MM	MM	E	E	E	(MM)
Routing Flexibility								E	MM	(MM)	MM	MM	MM	E	MM	(MM)	(MM)	(MM)	(MM)
Topography and Topology									E	(SM)	E	E	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Community Environment										E	SM	SM	SM	MM	SM	MM	MM	MM	MM
Human-related Safety											E	E	E	E	E	(MM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	E	E	E	(MM)	(MM)	(MM)	(MM)
Property-related Security													E	E	E	(MM)	(MM)	(MM)	(MM)
Maintenance														E	E	E	E	E	E
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	(MM)	(MM)
Time in non-Production																	E	(MM)	(MM)
Production Characteristics																		E	E
Other Characteristics																			E

Table 96: Pairwise Comparison of Expert 3 with respect to Human-related Safety

Human-related Safety	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	MM	SM	MM	SM	VSM	VSM	(MM)	SM	SM	SM	SM	MM	MM	MM	SM
Inventory Cost		E	E	E	E	MM	E	MM	SM	SM	(MM)	MM	MM	MM	MM	E	E	E	MM
Space Relationship			E	E	E	MM	E	MM	SM	SM	(MM)	MM	MM	MM	MM	E	E	E	MM
Material Flow				E	E	MM	E	MM	SM	SM	(MM)	MM	MM	MM	MM	E	E	E	MM
Non-Material Flow					E	MM	E	MM	SM	SM	(MM)	MM	MM	MM	MM	E	E	E	MM
Robustness						E	(MM)	E	MM	MM	(SM)	E	E	E	E	(MM)	(MM)	(MM)	(MM)
Volume Flexibility							E	MM	SM	SM	(MM)	MM	MM	MM	MM	E	E	MM	MM
Routing Flexibility								E	MM	MM	(MM)	E	E	E	E	E	E	E	E
Topography and Topology									E	E	(SM)	E	E	E	E	(MM)	(MM)	E	(MM)
Community Environment										E	(SM)	E	E	E	E	(MM)	(MM)	E	(MM)
Human-related Safety											E	SM	SM	MM	SM	MM	MM	MM	MM
Worker-related Comfort												E	E	E	E	(MM)	(MM)	(MM)	(MM)
Property-related Security													E	E	E	(MM)	(MM)	(MM)	E
Maintenance														E	E	(MM)	(MM)	(MM)	E
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 97: Pairwise Comparison of Expert 3 with respect Worker-related Comfort

Worker-related Comfort	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	MM	SM	MM	SM	VSM	VSM	SM	(MM)	SM	SM	SM	MM	MM	MM	SM
Inventory Cost		E	E	E	E	MM	E	MM	SM	SM	MM	(MM)	MM	MM	MM	E	E	E	MM
Space Relationship			E	E	E	MM	E	MM	SM	SM	MM	(MM)	MM	MM	MM	E	E	E	MM
Material Flow				E	E	MM	E	MM	SM	SM	MM	(MM)	MM	MM	MM	E	E	E	MM
Non-Material Flow					E	MM	E	MM	SM	SM	MM	(MM)	MM	MM	MM	E	E	E	MM
Robustness						E	(MM)	E	MM	MM	E	(SM)	E	E	E	(MM)	(MM)	(MM)	(MM)
Volume Flexibility							E	MM	SM	SM	MM	(MM)	MM	MM	MM	E	E	MM	MM
Routing Flexibility								E	MM	MM	E	(MM)	E	E	E	E	E	E	E
Topography and Topology									E	E	E	(SM)	E	E	E	(MM)	(MM)	E	(MM)
Community Environment										E	E	(SM)	E	E	E	(MM)	(MM)	E	(MM)
Human-related Safety											E	(SM)	E	E	E	(MM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	SM	SM	SM	MM	MM	MM	MM
Property-related Security													E	E	E	(MM)	(MM)	(MM)	E
Maintenance														E	E	(MM)	(MM)	(MM)	E
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	E	E
Time in non-Production																	E	(MM)	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 98: Pairwise Comparison of Expert 3 with respect Property-related Security

Property-related Security	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	(MM)	MM	MM	MM	MM	MM	SM
Inventory Cost		E	E	E	E	MM	E	MM	MM	MM	MM	MM	(MM)	MM	MM	E	E	E	MM
Space Relationship			E	E	E	MM	E	E	SM	SM	MM	MM	(MM)	MM	MM	E	E	E	MM
Material Flow				E	E	MM	E	MM	SM	SM	MM	MM	(MM)	MM	MM	E	E	E	MM
Non-Material Flow					E	E	E	E	SM	SM	E	E	(MM)	E	E	E	E	E	E
Robustness						E	(MM)	E	MM	MM	E	E	(SM)	E	E	(MM)	(MM)	E	E
Volume Flexibility							E	MM	SM	SM	MM	MM	(MM)	MM	MM	MM	MM	MM	MM
Routing Flexibility								E	MM	MM	MM	MM	(MM)	MM	MM	E	E	E	E
Topography and Topology									E	E	(MM)	(MM)	(SM)	E	E	(MM)	(MM)	(MM)	(MM)
Community Environment										E	(MM)	(MM)	(SM)	(MM)	E	(MM)	(MM)	(MM)	(MM)
Human-related Safety											E	E	(SM)	(MM)	E	(MM)	(MM)	E	E
Worker-related Comfort												E	(SM)	(MM)	E	(MM)	(MM)	E	E
Property-related Security													E	MM	SM	MM	MM	MM	SM
Maintenance														E	E	(MM)	(MM)	(MM)	(MM)
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 99: Pairwise Comparison of Expert 3 with respect Maintenance

Maintenance	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	SM	SM	MM	SM	SM	SM	SM	MM	MM	(MM)	MM	MM	E	MM	MM
Inventory Cost		E	(MM)	(MM)	MM	MM	E	MM	MM	MM	MM	E	E	(MM)	E	E	(MM)	E	E
Space Relationship			E	E	SM	SM	MM	SM	SM	SM	SM	MM	MM	(MM)	MM	MM	E	MM	MM
Material Flow				E	SM	SM	MM	SM	SM	SM	SM	MM	MM	(MM)	MM	MM	E	MM	MM
Non-Material Flow					E	E	(MM)	E	E	E	E	(MM)	(MM)	(SM)	(MM)	(MM)	(SM)	(MM)	(MM)
Robustness						E	(MM)	E	E	E	E	(MM)	(MM)	(SM)	(MM)	(MM)	(SM)	(MM)	(MM)
Volume Flexibility							E	MM	MM	MM	MM	MM	MM	(MM)	MM	E	E	E	E
Routing Flexibility								E	E	E	E	(MM)	(MM)	(SM)	(MM)	(MM)	(SM)	(MM)	(MM)
Topography and Topology									E	E	E	(MM)	(MM)	(SM)	(MM)	(MM)	(SM)	(MM)	(MM)
Community Environment										E	E	(MM)	(MM)	(SM)	(MM)	(MM)	(SM)	(MM)	(MM)
Human-related Safety											E	(MM)	(MM)	(VSM)	(MM)	(MM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	E	(SM)	E	E	E	E	E
Property-related Security													E	(SM)	E	E	E	E	E
Maintenance														E	SM	MM	MM	MM	SM
Sustainability															E	(MM)	(MM)	E	E
Time in Production																E	(MM)	(MM)	E
Time in non-Production																	E	(MM)	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 100: Pairwise Comparison of Expert 3 with respect Sustainability

Sustainability	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	SM	SM	MM	SM	SM	SM	SM	MM	MM	MM	(MM)	MM	E	MM	MM
Inventory Cost		E	(MM)	(MM)	MM	MM	E	MM	MM	MM	MM	E	E	E	(MM)	E	(MM)	E	E
Space Relationship			E	E	SM	SM	MM	SM	SM	SM	SM	MM	MM	MM	(MM)	MM	E	MM	MM
Material Flow				E	SM	SM	MM	SM	SM	SM	SM	MM	MM	MM	(MM)	MM	E	MM	MM
Non-Material Flow					E	E	(MM)	E	E	E	E	(MM)	(MM)	(MM)	(SM)	(MM)	(SM)	(MM)	(MM)
Robustness						E	(MM)	E	E	E	E	(MM)	(MM)	(MM)	(SM)	(MM)	(SM)	(MM)	(MM)
Volume Flexibility							E	MM	MM	MM	MM	MM	MM	MM	(MM)	E	E	E	E
Routing Flexibility								E	E	E	E	(MM)	(MM)	(MM)	(SM)	(MM)	(SM)	(MM)	(MM)
Topography and Topology									E	E	E	(MM)	(MM)	(MM)	(SM)	(MM)	(SM)	(MM)	(MM)
Community Environment										E	E	(MM)	(MM)	(MM)	(SM)	(MM)	(SM)	(MM)	(MM)
Human-related Safety											E	(MM)	(MM)	(MM)	(SM)	(MM)	(MM)	(MM)	(MM)
Worker-related Comfort												E	E	(MM)	(SM)	E	E	E	E
Property-related Security													E	(MM)	(SM)	E	E	E	E
Maintenance														E	(MM)	(MM)	(MM)	(MM)	(MM)
Sustainability															E	MM	MM	MM	MM
Time in Production																E	(MM)	(MM)	E
Time in non-Production																	E	(MM)	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 101: Pairwise Comparison of Expert 3 with respect Time in Production

Time in Production	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	E	E	E	(MM)	MM	(SM)	(MM)	E	E
Inventory Cost		E	E	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	E	E	E	(MM)	E	(SM)	(MM)	E	E
Space Relationship			E	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	E	E	E	E	MM	(MM)	(MM)	E	E
Material Flow				E	E	SM	E	E	MM	MM	E	E	E	E	MM	(MM)	E	E	E
Non-Material Flow					E	SM	E	E	MM	MM	E	E	E	E	MM	(MM)	E	E	E
Robustness						E	(MM)	(MM)	MM	MM	E	E	E	E	E	(SM)	(MM)	(MM)	(MM)
Volume Flexibility							E	E	MM	MM	E	E	E	E	MM	(MM)	E	E	E
Routing Flexibility								E	MM	MM	E	E	E	E	MM	(MM)	E	E	E
Topography and Topology									E	E	(MM)	(SM)	E	(MM)	E	(SM)	(MM)	(MM)	(MM)
Community Environment										E	(MM)	(SM)	E	(MM)	E	(SM)	(MM)	(MM)	E
Human-related Safety											E	E	MM	E	MM	(MM)	(MM)	E	E
Worker-related Comfort												E	MM	E	MM	(MM)	E	E	E
Property-related Security													E	(MM)	E	(SM)	(MM)	(MM)	(MM)
Maintenance														E	MM	(MM)	E	E	E
Sustainability															E	(SM)	(MM)	E	E
Time in Production																E	MM	SM	SM
Time in non-Production																	E	MM	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 102: Pairwise Comparison of Expert 3 with respect Time in Non-Production

Time in non-Production	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	E	E	E	(MM)	MM	(MM)	(SM)	E	E
Inventory Cost		E	(MM)	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	E	(MM)	E	(MM)	E	(MM)	(SM)	E	E
Space Relationship			E	(MM)	(MM)	MM	(MM)	(MM)	MM	MM	E	E	E	(MM)	MM	(MM)	(SM)	E	E
Material Flow				E	E	SM	E	E	MM	MM	E	E	E	E	MM	E	(MM)	MM	MM
Non-Material Flow					E	SM	E	E	MM	MM	E	E	E	E	MM	E	(MM)	MM	MM
Robustness						E	(MM)	(MM)	MM	MM	E	E	E	E	E	(MM)	(SM)	(MM)	(MM)
Volume Flexibility							E	E	MM	MM	E	E	E	E	MM	E	(MM)	E	E
Routing Flexibility								E	MM	MM	E	E	E	E	MM	E	(MM)	E	E
Topography and Topology									E	E	E	(MM)	E	(MM)	E	(MM)	(SM)	(MM)	(MM)
Community Environment										E	E	(MM)	E	(MM)	E	(MM)	(SM)	(MM)	E
Human-related Safety											E	E	MM	E	MM	E	(MM)	E	E
Worker-related Comfort												E	MM	E	MM	E	(MM)	E	E
Property-related Security													E	(MM)	E	(MM)	(SM)	(MM)	(MM)
Maintenance														E	MM	E	(MM)	E	E
Sustainability															E	(MM)	(SM)	E	E
Time in Production																E	(MM)	MM	MM
Time in non-Production																	E	SM	SM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 103: Pairwise Comparison of Expert 3 with respect Production Characteristics

Production Characteristics	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	E	E	MM	E	MM	MM	MM	E	E	E	E	MM	E	E	(MM)	E
Inventory Cost		E	E	(MM)	(MM)	MM	E	E	MM	MM	E	E	E	E	MM	E	E	(MM)	E
Space Relationship			E	E	E	MM	E	E	MM	MM	E	E	E	MM	MM	E	E	(MM)	E
Material Flow				E	E	MM	E	MM	MM	MM	E	E	E	MM	MM	E	E	(MM)	E
Non-Material Flow					E	MM	E	E	MM	MM	E	E	E	MM	MM	E	E	(MM)	E
Robustness						E	(MM)	(MM)	MM	MM	E	E	E	E	MM	(MM)	(MM)	(SM)	(MM)
Volume Flexibility							E	E	MM	MM	E	E	E	E	MM	E	E	(MM)	E
Routing Flexibility								E	MM	MM	E	E	E	E	MM	E	E	(MM)	E
Topography and Topology									E	MM	E	E	E	(MM)	E	(MM)	(MM)	(SM)	(MM)
Community Environment										E	(MM)	(MM)	(MM)	(MM)	E	(MM)	(MM)	(SM)	(MM)
Human-related Safety											E	(MM)	E	(MM)	E	(MM)	(MM)	(SM)	(MM)
Worker-related Comfort												E	MM	(MM)	E	(MM)	(MM)	(SM)	(MM)
Property-related Security													E	(MM)	E	(MM)	(MM)	(SM)	(MM)
Maintenance														E	MM	E	E	(MM)	E
Sustainability															E	(MM)	(MM)	(SM)	(MM)
Time in Production																E	E	(MM)	E
Time in non-Production																	E	(MM)	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 104: Pairwise Comparison of Expert 3 with respect Other Characteristics

Other Characteristics	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	E	E	E	MM	MM	MM	MM	E	(MM)
Inventory Cost		E	E	E	E	MM	E	E	MM	MM	E	E	E	MM	MM	E	E	E	(MM)
Space Relationship			E	E	E	MM	E	E	MM	MM	E	E	E	E	MM	E	E	E	(MM)
Material Flow				E	E	MM	E	MM	MM	MM	E	E	MM	MM	MM	E	E	E	(MM)
Non-Material Flow					E	MM	E	E	MM	MM	E	E	E	MM	MM	E	E	E	(MM)
Robustness						E	(MM)	(MM)	MM	MM	E	E	E	E	MM	(MM)	(MM)	(MM)	(SM)
Volume Flexibility							E	E	MM	MM	E	E	E	E	MM	E	E	E	(MM)
Routing Flexibility								E	MM	MM	E	E	E	E	MM	E	E	E	(MM)
Topography and Topology									E	MM	E	E	E	(MM)	E	(MM)	(MM)	(MM)	(SM)
Community Environment										E	(MM)	(MM)	E	(MM)	E	(MM)	(MM)	(MM)	(SM)
Human-related Safety											E	E	MM	E	MM	(MM)	(MM)	(MM)	(SM)
Worker-related Comfort												E	MM	E	MM	(MM)	(MM)	(MM)	(SM)
Property-related Security													E	(MM)	E	(MM)	(MM)	(MM)	(SM)
Maintenance														E	E	E	E	E	(MM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 105: Pairwise Comparison of Expert 4 with respect to Non-Inventory Cost

Non-Inventory Cost	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	SM	MM	MM	SM	SM	MM	MM	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Inventory Cost		E	(MM)	(MM)	E	E	E	E	E	E	E	E	E	E	E	E	E	E	MM
Space Relationship			E	E	MM	MM	E	E	E	E	E	E	E	E	E	E	E	E	MM
Material Flow				E	MM	MM	E	E	E	E	E	E	E	E	E	E	E	E	MM
Non-Material Flow					E	E	(MM)	E	E	E	E	E	E	(MM)	(MM)	(MM)	E	E	E
Robustness						E	(MM)	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	E
Volume Flexibility							E	E	E	E	E	E	E	E	E	E	E	E	E
Routing Flexibility								E	(MM)	(MM)	E	E	E	E	E	E	E	E	MM
Topography and Topology									E	E	E	E	E	E	E	(MM)	(MM)	(MM)	(MM)
Community Environment										E	E	E	E	E	E	(MM)	(MM)	(MM)	(MM)
Human-related Safety											E	E	MM	E	E	(MM)	(MM)	(MM)	E
Worker-related Comfort												E	MM	E	E	(MM)	(MM)	(MM)	E
Property-related Security													E	E	E	E	E	E	E
Maintenance														E	E	(MM)	(MM)	(MM)	E
Sustainability															E	(MM)	(MM)	(MM)	E
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 106: Pairwise Comparison of Expert 4 with respect to Inventory Cost

Inventory Cost	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	(MM)	E	E	E	MM	E	E	MM	MM	MM	MM	MM	E	E	MM	MM	MM	MM
Inventory Cost		E	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Space Relationship			E	E	E	MM	E	E	MM	MM	E	E	E	E	E	(MM)	(MM)	E	MM
Material Flow				E	E	MM	E	E	MM	MM	E	E	E	E	E	E	E	E	E
Non-Material Flow					E	MM	E	E	E	E	(MM)	(MM)	E	(MM)	E	(MM)	(MM)	(MM)	(MM)
Robustness						E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	E	E
Volume Flexibility							E	E	E	E	E	E	E	E	E	(MM)	(MM)	E	MM
Routing Flexibility								E	E	E	(MM)	(MM)	E	E	E	(MM)	(MM)	(MM)	(MM)
Topography and Topology									E	E	E	E	E	E	E	(MM)	(MM)	(MM)	E
Community Environment										E	E	E	E	E	E	(MM)	(MM)	(MM)	E
Human-related Safety											E	E	MM	E	E	(MM)	(MM)	(MM)	MM
Worker-related Comfort												E	MM	E	E	(MM)	(MM)	(MM)	MM
Property-related Security													E	E	E	(MM)	(MM)	(MM)	E
Maintenance														E	MM	E	E	E	E
Sustainability															E	(MM)	(MM)	(MM)	E
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 107: Pairwise Comparison of Expert 4 with respect to Space Relationship

Space Relationship	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	(MM)	E	MM	MM	MM	MM	MM	MM	E	E	MM	MM	MM	MM	MM	MM	MM
Inventory Cost		E	(SM)	(MM)	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Space Relationship			E	MM	MM	SM	SM	SM	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	SM
Material Flow				E	MM	MM	MM	MM	E	E	E	E	E	E	E	E	E	E	MM
Non-Material Flow					E	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	E
Robustness						E	E	E	(MM)	(MM)	(MM)	(MM)	E	E	E	(MM)	(MM)	(MM)	E
Volume Flexibility							E	MM	E	E	E	E	E	E	E	E	E	E	MM
Routing Flexibility								E	E	E	E	E	E	E	E	(MM)	(MM)	E	E
Topography and Topology									E	E	E	E	E	E	E	(MM)	(MM)	E	E
Community Environment										E	E	E	E	E	E	(MM)	(MM)	E	E
Human-related Safety											E	E	MM	E	E	(MM)	(MM)	E	MM
Worker-related Comfort												E	MM	E	E	(MM)	(MM)	E	MM
Property-related Security													E	(MM)	E	(MM)	E	E	E
Maintenance														E	MM	E	E	E	E
Sustainability															E	(MM)	(MM)	E	E
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 108: Pairwise Comparison of Expert 4 with respect to Material Flow

Material Flow	Non-Inventor y Cost	Inventor y Cost	Space Relationshi p	Materia l Flow	Non-Materia l Flow	Robustnes s	Volume Flexibilit y	Routing Flexibilit y	Topograph y and Topology	Community Environmen t	Human -related Safety	Worker -related Comfor t	Property -related Security	Maintenanc e	Sustainabilit y	Time in Productio n	Time in non-Productio n	Production Characteristic s	Other Characteristic s
Non-Inventory Cost	E	E	MM	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Inventory Cost		E	MM	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Space Relationship			E	(MM)	MM	E	E	E	E	E	E	E	E	E	E	E	E	MM	MM
Material Flow				E	SM	SM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Non-Material Flow					E	E	(MM)	(SM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	E	E
Robustness						E	(MM)	E	E	E	(MM)	E	E	E	E	(MM)	(MM)	E	E
Volume Flexibility							E	E	E	E	E	E	E	E	E	(MM)	(MM)	E	MM
Routing Flexibility								E	E	E	E	E	E	E	E	(MM)	(MM)	E	E
Topography and Topology									E	E	E	E	MM	E	E	(MM)	(MM)	(MM)	E
Community Environment										E	E	E	MM	E	E	(MM)	E	E	E
Human-related Safety											E	E	MM	E	MM	E	E	E	E
Worker-related Comfort												E	MM	E	MM	E	E	E	E
Property-related Security													E	(MM)	E	(MM)	(MM)	E	E
Maintenance														E	MM	E	E	E	MM
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristic s																		E	E
Other Characteristic s																			E

Table 109: Pairwise Comparison of Expert 4 with respect to Non-Material Flow

Non-Material Flow	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	(MM)	(MM)	E	(SM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	E	E	E
Inventory Cost		E	E	MM	(MM)	MM	MM	E	E	E	E	E	MM	E	MM	MM	MM	MM	MM
Space Relationship			E	MM	(MM)	MM	MM	E	E	E	E	E	E	E	MM	MM	MM	MM	MM
Material Flow				E	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	E	E	E
Non-Material Flow					E	SM	SM	MM	MM	MM	MM	MM	SM	SM	SM	SM	SM	SM	SM
Robustness						E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	E	E	E
Volume Flexibility							E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	E	E	E
Routing Flexibility								E	E	E	E	E	MM	E	MM	MM	E	MM	E
Topography and Topology									E	E	E	E	E	MM	MM	MM	MM	MM	MM
Community Environment										E	E	E	E	MM	MM	MM	MM	MM	MM
Human-related Safety											E	E	E	MM	MM	MM	MM	MM	MM
Worker-related Comfort												E	E	MM	MM	MM	MM	MM	MM
Property-related Security													E	MM	MM	MM	MM	MM	MM
Maintenance														E	E	E	E	E	E
Sustainability															E	E	E	E	E
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 110: Pairwise Comparison of Expert 4 with respect to Robustness

Robustness	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	MM	MM	MM	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Inventory Cost		E	MM	MM	MM	(MM)	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Space Relationship			E	E	E	(SM)	E	E	E	E	E	E	E	E	E	E	E	E	E
Material Flow				E	E	(SM)	E	E	E	E	E	E	E	E	E	E	E	E	E
Non-Material Flow					E	(SM)	E	E	E	E	E	E	E	E	E	E	E	E	E
Robustness						E	SM	SM	MM	MM	MM	MM	SM	MM	SM	MM	MM	MM	MM
Volume Flexibility							E	E	E	E	E	E	MM	E	MM	E	E	E	E
Routing Flexibility								E	E	E	E	E	MM	E	MM	E	E	E	E
Topography and Topology									E	E	E	E	MM	E	MM	E	E	E	E
Community Environment										E	E	E	MM	E	MM	E	E	E	E
Human-related Safety											E	E	E	E	E	E	E	E	E
Worker-related Comfort												E	MM	E	E	E	E	E	E
Property-related Security													E	(MM)	E	(MM)	(MM)	(MM)	E
Maintenance														E	MM	E	E	E	MM
Sustainability															E	(MM)	(MM)	(MM)	E
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 111: Pairwise Comparison of Expert 4 with respect to Volume Flexibility

Volume Flexibility	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	MM	MM	(MM)	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Inventory Cost		E	E	E	MM	MM	(MM)	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Space Relationship			E	E	MM	MM	(MM)	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Material Flow				E	MM	MM	(MM)	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Non-Material Flow					E	E	(SM)	(MM)	E	E	E	E	E	E	E	E	E	E	E
Robustness						E	(SM)	(MM)	E	E	E	E	E	E	E	E	E	E	E
Volume Flexibility							E	MM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM
Routing Flexibility								E	MM	MM	E	E	E	E	E	E	E	E	E
Topography and Topology									E	MM	E	E	E	E	MM	E	E	MM	E
Community Environment										E	(MM)	(MM)	MM	E	MM	E	E	MM	MM
Human-related Safety											E	(MM)	MM	E	MM	E	E	MM	MM
Worker-related Comfort												E	MM	E	MM	E	E	MM	MM
Property-related Security													E	E	MM	E	E	MM	MM
Maintenance														E	MM	E	E	E	MM
Sustainability															E	(MM)	(MM)	(MM)	E
Time in Production																E	E	E	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 112: Pairwise Comparison of Expert 4 with respect to Routing Flexibility

Routing Flexibility	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	MM	E	E	(MM)	E	E	E	E	MM	E	MM	E	E	MM	E
Inventory Cost		E	E	E	MM	E	E	(MM)	E	E	E	E	E	E	MM	E	E	MM	E
Space Relationship			E	E	MM	E	E	(MM)	E	E	E	E	E	E	MM	E	E	MM	E
Material Flow				E	MM	E	E	(MM)	E	E	E	E	E	E	MM	E	E	MM	E
Non-Material Flow					E	(MM)	(MM)	(SM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	E	(MM)	(MM)	E	(MM)
Robustness						E	(MM)	(SM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	(MM)
Volume Flexibility							E	(MM)	E	E	E	E	E	E	MM	E	E	MM	E
Routing Flexibility								E	MM	MM	MM	MM	MM	MM	SM	MM	MM	MM	E
Topography and Topology									E	E	E	E	E	MM	MM	MM	MM	MM	E
Community Environment										E	E	E	E	MM	MM	MM	MM	MM	E
Human-related Safety											E	E	E	MM	MM	MM	MM	MM	E
Worker-related Comfort												E	E	MM	MM	MM	MM	MM	E
Property-related Security													E	E	E	MM	MM	E	E
Maintenance														E	MM	E	E	MM	E
Sustainability															E	(MM)	(MM)	E	(MM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 113: Pairwise Comparison of Expert 4 with respect to Topography and Topology

Topography and Topology	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	MM	MM	E	E	(SM)	(MM)	(MM)	E	E	E	E	E	E	E	(MM)
Inventory Cost		E	E	E	E	E	E	E	(SM)	(MM)	(MM)	E	E	E	MM	E	E	E	(MM)
Space Relationship			E	E	E	E	E	E	(SM)	(MM)	(MM)	E	E	E	MM	E	E	E	(MM)
Material Flow				E	E	MM	E	E	(SM)	(MM)	(MM)	E	E	E	MM	E	E	E	(MM)
Non-Material Flow					E	E	(MM)	(MM)	(VSM)	(SM)	(MM)	(MM)	(MM)	(MM)	E	(MM)	(MM)	(MM)	(SM)
Robustness						E	(MM)	(MM)	(VSM)	(SM)	(MM)	(MM)	E	E	E	(MM)	(MM)	E	(MM)
Volume Flexibility							E	MM	(SM)	(MM)	(MM)	(MM)	E	E	E	E	E	E	(MM)
Routing Flexibility								E	(SM)	(MM)	(MM)	(MM)	E	E	E	E	E	E	(MM)
Topography and Topology									E	MM	MM	MM	SM	SM	SM	SM	SM	SM	MM
Community Environment										E	E	E	MM	MM	MM	MM	MM	MM	E
Human-related Safety											E	E	E	MM	MM	MM	MM	MM	E
Worker-related Comfort												E	E	MM	MM	MM	MM	MM	E
Property-related Security													E	MM	MM	MM	MM	MM	E
Maintenance														E	E	E	E	E	(MM)
Sustainability															E	E	E	E	(MM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 114: Pairwise Comparison of Expert 4 with respect to Community Environment

Community Environment	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	MM	MM	E	E	(MM)	(SM)	(MM)	E	E	E	E	E	E	E	(MM)
Inventory Cost		E	E	E	E	E	E	E	(MM)	(SM)	(MM)	E	E	E	MM	E	E	E	(MM)
Space Relationship			E	E	E	E	E	E	(MM)	(SM)	(MM)	E	E	E	MM	E	E	E	(MM)
Material Flow				E	E	MM	E	E	(MM)	(SM)	(MM)	E	E	E	MM	E	E	E	(MM)
Non-Material Flow					E	E	(MM)	(MM)	(SM)	(VSM)	(MM)	(MM)	(MM)	(MM)	E	(MM)	(MM)	(MM)	(SM)
Robustness						E	(MM)	(MM)	(MM)	(SM)	(MM)	(MM)	E	E	E	(MM)	(MM)	E	(MM)
Volume Flexibility							E	MM	(MM)	(SM)	(MM)	(MM)	E	E	E	E	E	E	(MM)
Routing Flexibility								E	(MM)	(SM)	(MM)	(MM)	E	E	E	E	E	E	(MM)
Topography and Topology									E	(MM)	E	E	MM	E	MM	MM	MM	E	E
Community Environment										E	MM	MM	SM	SM	SM	MM	MM	MM	MM
Human-related Safety											E	E	E	MM	MM	MM	MM	MM	E
Worker-related Comfort												E	E	MM	MM	MM	MM	MM	E
Property-related Security													E	MM	MM	MM	MM	MM	E
Maintenance														E	E	E	E	E	(MM)
Sustainability															E	E	E	E	(MM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 115: Pairwise Comparison of Expert 4 with respect to Human-related Safety

Human-related Safety	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	MM	E	E	E	(MM)	(MM)	(SM)	(MM)	E	E	E	E	E	E	(MM)
Inventory Cost		E	E	E	MM	E	E	E	(MM)	(MM)	(SM)	(MM)	E	E	E	E	E	E	(MM)
Space Relationship			E	E	MM	E	E	E	(MM)	(MM)	(SM)	(MM)	E	E	E	E	E	E	(MM)
Material Flow				E	MM	E	E	E	(MM)	(MM)	(SM)	(MM)	E	E	E	E	E	E	(MM)
Non-Material Flow					E	(MM)	(MM)	(MM)	(SM)	(SM)	(VSM)	(SM)	(MM)	(MM)	E	(MM)	(MM)	(MM)	(SM)
Robustness						E	E	E	E	E	(MM)	(MM)	E	E	E	E	E	E	(MM)
Volume Flexibility							E	E	(MM)	(MM)	(SM)	(MM)	E	E	E	E	E	MM	(MM)
Routing Flexibility								E	(MM)	(MM)	(SM)	(MM)	E	E	E	(MM)	(MM)	E	(MM)
Topography and Topology									E	E	(MM)	E	E	MM	MM	MM	MM	MM	E
Community Environment										E	(MM)	E	E	MM	MM	MM	MM	MM	E
Human-related Safety											E	MM	MM	SM	SM	SM	SM	SM	MM
Worker-related Comfort												E	E	MM	MM	MM	MM	MM	E
Property-related Security													E	MM	MM	MM	MM	MM	E
Maintenance														E	E	(MM)	(MM)	(MM)	(SM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 116: Pairwise Comparison of Expert 4 with respect Worker-related Comfort

Worker-related Comfort	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	MM	E	E	E	(MM)	(MM)	(MM)	(SM)	E	E	E	E	E	E	(MM)
Inventory Cost		E	E	E	MM	E	E	E	(MM)	(MM)	(MM)	(SM)	E	E	E	E	E	E	(MM)
Space Relationship			E	E	MM	E	E	E	(MM)	(MM)	(MM)	(SM)	E	E	E	E	E	E	(MM)
Material Flow				E	MM	E	E	E	(MM)	(MM)	(MM)	(SM)	E	E	E	E	E	E	(MM)
Non-Material Flow					E	(MM)	(MM)	(MM)	(SM)	(SM)	(SM)	(VSM)	(MM)	(MM)	E	(MM)	(MM)	(MM)	(SM)
Robustness						E	E	E	E	E	(MM)	(SM)	E	E	E	E	E	E	(MM)
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(SM)	E	E	E	E	E	MM	(MM)
Routing Flexibility								E	(MM)	(MM)	(MM)	(SM)	E	E	E	(MM)	(MM)	E	(MM)
Topography and Topology									E	E	E	(MM)	E	MM	MM	MM	MM	MM	E
Community Environment										E	E	(MM)	E	MM	MM	MM	MM	MM	E
Human-related Safety											E	(MM)	MM	MM	MM	MM	MM	MM	E
Worker-related Comfort												E	MM	SM	SM	SM	SM	SM	MM
Property-related Security													E	E	MM	MM	MM	MM	E
Maintenance														E	E	(MM)	(MM)	(MM)	(SM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 117: Pairwise Comparison of Expert 4 with respect Property-related Security

Property-related Security	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	(SM)	E	E	E	E	E	(MM)
Inventory Cost		E	E	E	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	(SM)	E	E	E	E	E	(MM)
Space Relationship			E	E	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	(SM)	E	E	E	E	E	(MM)
Material Flow				E	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	(SM)	E	E	E	E	E	(MM)
Non-Material Flow					E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(SM)	(MM)	E	(MM)	(MM)	(MM)	(MM)
Robustness						E	E	E	E	E	(MM)	(MM)	(SM)	E	E	E	E	E	(MM)
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(SM)	E	E	E	E	MM	(MM)
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(SM)	E	E	(MM)	(MM)	E	(MM)
Topography and Topology									E	E	E	E	(MM)	MM	MM	MM	MM	MM	E
Community Environment										E	E	E	(MM)	MM	MM	MM	MM	MM	E
Human-related Safety											E	E	(MM)	MM	MM	MM	MM	MM	E
Worker-related Comfort												E	(MM)	MM	MM	MM	MM	MM	E
Property-related Security													E	SM	SM	SM	SM	SM	MM
Maintenance														E	E	(MM)	(MM)	(MM)	(SM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 118: Pairwise Comparison of Expert 4 with respect Maintenance

Maintenance	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	E	E	MM	E	MM	MM	E	E	E	E	E	(MM)	MM	MM	E	E	E
Inventory Cost		E	(MM)	(MM)	MM	E	E	MM	E	E	E	E	E	(MM)	E	E	(MM)	E	E
Space Relationship			E	E	MM	E	E	MM	(MM)	(MM)	(MM)	(MM)	E	(MM)	MM	MM	E	E	E
Material Flow				E	MM	E	E	MM	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	E
Non-Material Flow					E	E	(MM)	E	E	E	E	(MM)	(MM)	(SM)	E	(MM)	(SM)	(MM)	(MM)
Robustness						E	(MM)	E	E	E	E	E	E	(MM)	E	E	E	(MM)	(MM)
Volume Flexibility							E	MM	E	E	E	E	E	(MM)	E	E	E	(MM)	(MM)
Routing Flexibility								E	E	E	(MM)	(MM)	E	(SM)	E	E	E	(MM)	(MM)
Topography and Topology									E	E	E	E	E	(MM)	MM	E	E	E	E
Community Environment										E	E	E	E	(MM)	MM	E	E	E	E
Human-related Safety											E	E	E	(MM)	MM	E	E	E	E
Worker-related Comfort												E	E	(MM)	MM	E	E	E	E
Property-related Security													E	(MM)	MM	E	E	E	E
Maintenance														E	SM	MM	MM	MM	MM
Sustainability															E	(MM)	(MM)	E	(MM)
Time in Production																E	(MM)	E	(MM)
Time in non-Production																	E	MM	E
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 119: Pairwise Comparison of Expert 4 with respect Sustainability

Sustainability	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	MM	E	MM	MM	E	E	E	E	E	E	(MM)	E	(MM)	E	(MM)
Inventory Cost		E	E	E	MM	E	MM	MM	E	E	E	E	E	E	(MM)	E	(MM)	E	(MM)
Space Relationship			E	E	MM	E	MM	MM	E	E	E	E	E	E	(MM)	E	(MM)	E	E
Material Flow				E	MM	E	MM	MM	E	E	E	E	E	E	(MM)	E	(MM)	E	E
Non-Material Flow					E	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(SM)	(MM)	(SM)	(MM)	(SM)
Robustness						E	MM	MM	E	E	E	E	E	E	(MM)	E	(MM)	E	(MM)
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	E	E	(MM)	E	E	E	(MM)
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(MM)	E	(MM)	E	E	E	(MM)
Topography and Topology									E	E	E	E	E	E	(MM)	E	E	E	(MM)
Community Environment										E	E	E	E	E	(MM)	E	E	E	(MM)
Human-related Safety											E	E	E	E	(MM)	E	E	E	(MM)
Worker-related Comfort												E	E	E	(MM)	E	E	E	(MM)
Property-related Security													E	E	(MM)	E	E	E	(MM)
Maintenance														E	(MM)	E	E	E	(MM)
Sustainability															E	SM	SM	SM	MM
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 120: Pairwise Comparison of Expert 4 with respect Time in Production

Time in Production	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	(MM)	E	E	E	E	E	E	E	E	E	E	E	(SM)	(MM)	E	E
Inventory Cost		E	E	(MM)	E	E	E	E	E	E	E	E	E	E	E	(SM)	(MM)	E	E
Space Relationship			E	(MM)	E	E	E	E	E	E	E	E	E	E	E	(SM)	(MM)	E	E
Material Flow				E	E	MM	MM	MM	E	E	MM	MM	MM	MM	MM	(MM)	E	MM	MM
Non-Material Flow					E	E	E	E	E	E	E	E	E	E	E	(SM)	(MM)	E	E
Robustness						E	E	E	E	E	E	E	E	E	E	(SM)	(MM)	E	E
Volume Flexibility							E	E	E	E	E	E	E	E	E	(SM)	(MM)	E	E
Routing Flexibility								E	E	E	E	E	E	E	E	(SM)	(MM)	E	E
Topography and Topology									E	E	E	E	E	E	E	(SM)	(MM)	E	E
Community Environment										E	E	E	E	E	E	(SM)	(MM)	E	E
Human-related Safety											E	E	E	E	E	(SM)	(MM)	E	E
Worker-related Comfort												E	E	E	E	(SM)	(MM)	E	E
Property-related Security													E	E	E	(SM)	(MM)	(MM)	(MM)
Maintenance														E	E	(SM)	(MM)	E	E
Sustainability															E	(SM)	(MM)	E	E
Time in Production																E	MM	SM	MM
Time in non-Production																	E	MM	E
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 121: Pairwise Comparison of Expert 4 with respect Time in Non-Production

Time in non-Production	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	(MM)	E	E	E	E	E	E	E	E	E	E	E	(MM)	(SM)	E	E
Inventory Cost		E	E	(MM)	E	E	E	E	E	E	E	E	E	E	E	(MM)	(SM)	E	E
Space Relationship			E	(MM)	E	E	E	E	E	E	E	E	E	E	E	(MM)	(SM)	E	E
Material Flow				E	E	MM	MM	MM	E	E	MM	MM	MM	MM	MM	E	(MM)	MM	MM
Non-Material Flow					E	E	E	E	E	E	E	E	E	E	E	(MM)	(SM)	E	E
Robustness						E	E	E	E	E	E	E	E	E	E	(MM)	(SM)	E	E
Volume Flexibility							E	E	E	E	E	E	E	E	E	(MM)	(SM)	E	E
Routing Flexibility								E	E	E	E	E	E	E	E	(MM)	(SM)	E	E
Topography and Topology									E	E	E	E	E	E	E	(MM)	(SM)	E	E
Community Environment										E	E	E	E	E	E	(MM)	(SM)	E	E
Human-related Safety											E	E	E	E	E	(MM)	(SM)	E	E
Worker-related Comfort												E	E	E	E	(MM)	(SM)	E	E
Property-related Security													E	E	E	(MM)	(SM)	(MM)	(MM)
Maintenance														E	E	(MM)	(SM)	E	E
Sustainability															E	(MM)	(SM)	E	E
Time in Production																E	(MM)	MM	E
Time in non-Production																	E	SM	MM
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 122: Pairwise Comparison of Expert 4 with respect Production Characteristics

Production Characteristics	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	E	E	E	E	MM	E	E	E	E	E	E	MM	E	E	(MM)	E
Inventory Cost		E	E	(MM)	(MM)	E	E	E	E	E	E	E	E	E	MM	E	E	(MM)	E
Space Relationship			E	E	E	E	E	E	E	E	E	E	E	MM	MM	E	E	(MM)	E
Material Flow				E	E	E	E	MM	E	E	E	E	E	MM	MM	E	E	(MM)	E
Non-Material Flow					E	E	E	E	E	E	E	E	E	MM	MM	E	E	(MM)	E
Robustness						E	(MM)	(MM)	E	E	E	E	E	E	MM	(MM)	(MM)	(SM)	(MM)
Volume Flexibility							E	E	E	E	E	E	E	E	MM	E	E	(MM)	E
Routing Flexibility								E	E	E	E	E	E	E	MM	E	E	(MM)	E
Topography and Topology									E	E	E	E	MM	E	E	E	E	(MM)	E
Community Environment										E	E	E	MM	E	E	E	E	(MM)	E
Human-related Safety											E	E	MM	E	E	E	E	(MM)	E
Worker-related Comfort												E	MM	E	E	E	E	(MM)	E
Property-related Security													E	(MM)	E	E	E	(MM)	E
Maintenance														E	E	(MM)	(MM)	(SM)	(MM)
Sustainability															E	(MM)	(MM)	(SM)	(MM)
Time in Production																E	E	(MM)	E
Time in non-Production																	E	(MM)	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 123: Pairwise Comparison of Expert 4 with respect Other Characteristics

Other Characteristics	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	MM	E	MM	MM	E	E	E	E	E	MM	MM	MM	MM	E	(MM)
Inventory Cost		E	E	E	E	E	E	E	E	E	E	E	E	MM	MM	MM	MM	E	(MM)
Space Relationship			E	E	E	E	E	E	E	E	E	E	E	E	MM	MM	MM	E	(MM)
Material Flow				E	E	E	E	MM	E	E	E	E	E	MM	MM	MM	MM	E	(MM)
Non-Material Flow					E	E	E	E	E	E	E	E	E	MM	MM	MM	MM	E	(MM)
Robustness						E	(MM)	(MM)	E	E	E	E	E	E	MM	E	E	(MM)	(SM)
Volume Flexibility							E	E	E	E	E	E	E	E	MM	E	E	E	(MM)
Routing Flexibility								E	E	E	E	E	E	E	MM	E	E	E	(MM)
Topography and Topology									E	E	E	E	E	E	MM	E	E	(MM)	(MM)
Community Environment										E	E	E	MM	MM	MM	E	E	(MM)	(MM)
Human-related Safety											E	E	MM	E	MM	E	E	(MM)	(MM)
Worker-related Comfort												E	MM	E	MM	E	E	(MM)	(MM)
Property-related Security													E	E	MM	E	E	E	(SM)
Maintenance														E	E	E	E	E	(MM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 124: Pairwise Comparison of Expert 5 with respect to Non-Inventory Cost

Non-Inventory Cost	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM	MM
Inventory Cost		E	E	E	MM	E	E	E	E	E	E	E	E	MM	MM	E	E	E	E
Space Relationship			E	E	MM	E	E	E	E	E	E	E	E	MM	MM	E	E	E	E
Material Flow				E	MM	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	E	E
Non-Material Flow					E	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	MM	(MM)	E	E	E
Robustness						E	E	E	E	E	E	E	E	MM	MM	(MM)	(MM)	(MM)	E
Volume Flexibility							E	E	E	E	E	E	E	E	E	E	E	E	E
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	E	E
Topography and Topology									E	E	E	E	E	MM	MM	E	E	E	E
Community Environment										E	E	E	E	MM	MM	E	E	E	E
Human-related Safety											E	E	MM	E	E	E	E	E	E
Worker-related Comfort												E	MM	E	E	E	E	E	E
Property-related Security													E	E	E	(MM)	(MM)	(MM)	(MM)
Maintenance														E	E	(MM)	(MM)	(MM)	E
Sustainability															E	(MM)	(MM)	(MM)	E
Time in Production																E	E	E	MM
Time in non-Production																	E	E	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 125: Pairwise Comparison of Expert 5 with respect to Inventory Cost

Inventory Cost	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	(MM)	E	E	E	E	E	MM	E	E	E	E	E	MM	MM	MM	MM	E	E
Inventory Cost		E	MM	MM	MM	MM	MM	SM	MM	MM	MM	MM	MM	SM	SM	SM	SM	MM	MM
Space Relationship			E	E	E	E	E	MM	E	E	E	E	E	MM	MM	MM	MM	E	E
Material Flow				E	E	E	E	E	E	E	E	E	E	MM	MM	MM	MM	E	E
Non-Material Flow					E	E	E	MM	E	E	(MM)	(MM)	E	E	E	E	E	(MM)	(MM)
Robustness						E	E	MM	(MM)	(MM)	(MM)	(MM)	(MM)	E	MM	(MM)	(MM)	(SM)	(SM)
Volume Flexibility							E	E	E	E	E	E	E	E	E	E	E	E	E
Routing Flexibility								E	E	E	(MM)	(MM)	E	E	MM	E	E	(MM)	(MM)
Topography and Topology									E	E	E	E	E	MM	MM	(MM)	(MM)	(MM)	(MM)
Community Environment										E	E	E	E	MM	MM	(MM)	(MM)	E	E
Human-related Safety											E	E	MM	MM	MM	E	E	E	E
Worker-related Comfort												E	MM	MM	MM	E	E	E	E
Property-related Security													E	E	MM	E	E	E	E
Maintenance														E	MM	E	E	E	E
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 126: Pairwise Comparison of Expert 5 with respect to Space Relationship

Space Relationship	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	(MM)	E	MM	E	MM	MM	E	E	E	E	E	MM	MM	MM	MM	E	E
Inventory Cost		E	(MM)	E	MM	E	MM	MM	E	E	E	E	E	MM	MM	MM	MM	E	E
Space Relationship			E	MM	SM	MM	MM	SM	MM	MM	MM	MM	MM	SM	SM	MM	MM	MM	MM
Material Flow				E	MM	E	MM	MM	E	E	E	E	E	MM	MM	MM	MM	E	E
Non-Material Flow					E	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	(MM)	(MM)	(MM)	(MM)
Robustness						E	MM	MM	E	E	E	E	E	MM	MM	E	E	(MM)	(MM)
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	E	MM	MM	E	E	E	E
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	E	MM	MM	E	E	(MM)	(MM)
Topography and Topology									E	E	E	E	E	MM	MM	E	E	E	E
Community Environment										E	E	E	E	MM	MM	E	E	E	E
Human-related Safety											E	E	MM	MM	MM	E	E	E	E
Worker-related Comfort												E	E	MM	MM	E	E	E	E
Property-related Security													E	MM	MM	E	E	E	E
Maintenance														E	MM	(MM)	(MM)	E	E
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	MM	MM
Time in non-Production																	E	E	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 127: Pairwise Comparison of Expert 5 with respect to Material Flow

Material Flow	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	(MM)	MM	E	MM	MM	E	E	E	E	E	MM	MM	MM	MM	MM	MM
Inventory Cost		E	E	(MM)	MM	E	MM	MM	E	E	E	E	E	MM	MM	MM	MM	MM	MM
Space Relationship			E	(MM)	MM	E	MM	MM	E	E	E	E	E	MM	MM	E	E	MM	MM
Material Flow				E	SM	MM	SM	SM	MM	MM	MM	MM	MM	SM	SM	MM	MM	SM	SM
Non-Material Flow					E	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	(MM)	(MM)	E	E
Robustness						E	MM	MM	E	E	(MM)	(MM)	E	MM	MM	E	E	E	E
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	E	MM
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	(MM)	(MM)	(MM)	(MM)
Topography and Topology									E	E	E	E	E	MM	MM	E	E	E	E
Community Environment										E	E	E	E	MM	MM	E	E	E	E
Human-related Safety											E	E	E	MM	MM	E	E	E	E
Worker-related Comfort												E	E	MM	MM	E	E	E	E
Property-related Security													E	MM	MM	E	E	E	E
Maintenance														E	MM	E	E	E	MM
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	E	MM
Time in non-Production																	E	E	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 128: Pairwise Comparison of Expert 5 with respect to Non-Material Flow

Non-Material Flow	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	(MM)	(MM)	E	(MM)	E	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	E	E
Inventory Cost		E	E	MM	(MM)	MM	MM	E	E	E	E	E	MM	MM	MM	E	E	MM	MM
Space Relationship			E	MM	(MM)	E	MM	E	E	E	E	E	E	MM	MM	E	E	E	E
Material Flow				E	(MM)	E	E	E	(MM)	(MM)	(MM)	(MM)	E	MM	MM	E	E	E	E
Non-Material Flow					E	MM	SM	SM	MM	MM	MM	MM	MM	SM	SM	MM	MM	MM	MM
Robustness						E	MM	MM	E	E	E	E	E	MM	MM	MM	MM	MM	MM
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	(MM)	(MM)	E	E
Routing Flexibility								E	E	(MM)	(MM)	(MM)	(MM)	MM	MM	(MM)	(MM)	E	E
Topography and Topology									E	E	E	E	E	MM	MM	MM	MM	MM	MM
Community Environment										E	E	E	E	MM	MM	MM	MM	MM	MM
Human-related Safety											E	E	E	MM	MM	MM	MM	MM	MM
Worker-related Comfort												E	E	MM	MM	MM	MM	MM	MM
Property-related Security													E	MM	MM	MM	MM	MM	MM
Maintenance														E	MM	E	E	E	E
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 129: Pairwise Comparison of Expert 5 with respect to Robustness

Robustness	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	MM	(MM)	MM	MM	E	E	E	E	E	MM	MM	MM	MM	MM	MM
Inventory Cost		E	E	E	MM	(MM)	MM	MM	E	E	E	E	E	MM	MM	MM	MM	MM	MM
Space Relationship			E	E	MM	(SM)	MM	MM	E	E	E	E	E	MM	MM	E	E	E	E
Material Flow				E	MM	(SM)	MM	MM	E	E	E	E	E	MM	MM	E	E	E	E
Non-Material Flow					E	(SM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	E	E
Robustness						E	SM	SM	MM	MM	MM	MM	MM	SM	SM	MM	MM	MM	MM
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	E	E
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	E	E
Topography and Topology									E	E	E	E	MM	MM	MM	E	E	E	E
Community Environment										E	E	E	MM	MM	MM	E	E	E	E
Human-related Safety											E	E	MM	MM	MM	E	E	E	E
Worker-related Comfort												E	MM	MM	MM	E	E	E	E
Property-related Security													E	MM	MM	E	E	E	E
Maintenance														E	MM	E	E	E	E
Sustainability															E	(MM)	(MM)	(MM)	E
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 130: Pairwise Comparison of Expert 5 with respect to Volume Flexibility

Volume Flexibility	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	MM	E	(MM)	E	E	E	E	E	E	MM	MM	MM	MM	MM	MM
Inventory Cost		E	E	E	MM	E	(MM)	E	E	E	E	E	E	MM	MM	E	E	MM	MM
Space Relationship			E	E	MM	E	(MM)	E	E	E	E	E	E	MM	MM	E	E	E	E
Material Flow				E	MM	E	(MM)	E	E	E	E	E	E	MM	MM	E	E	E	E
Non-Material Flow					E	(MM)	(SM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	(MM)	(MM)	(MM)	(MM)
Robustness						E	(MM)	E	E	E	E	E	E	MM	MM	E	E	E	E
Volume Flexibility							E	MM	MM	MM	MM	MM	MM	SM	SM	MM	MM	MM	MM
Routing Flexibility								E	E	E	E	E	E	MM	MM	E	E	E	E
Topography and Topology									E	E	E	E	E	MM	MM	E	E	MM	MM
Community Environment										E	(MM)	(MM)	E	MM	MM	E	E	E	E
Human-related Safety											E	E	E	MM	MM	E	E	E	E
Worker-related Comfort												E	E	MM	MM	E	E	E	E
Property-related Security													E	MM	MM	E	E	E	E
Maintenance														E	MM	(MM)	(MM)	(MM)	(MM)
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 131: Pairwise Comparison of Expert 5 with respect to Routing Flexibility

Routing Flexibility	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	E	E	E	(MM)	E	E	E	E	E	MM	MM	E	E	E	E
Inventory Cost		E	E	E	E	E	E	(MM)	E	E	E	E	E	MM	MM	E	E	E	E
Space Relationship			E	E	E	E	E	(MM)	E	E	E	E	E	MM	MM	E	E	E	E
Material Flow				E	E	E	E	(MM)	E	E	E	E	E	MM	MM	E	E	E	E
Non-Material Flow					E	(MM)	E	(SM)	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	(MM)	(MM)	(MM)	(MM)
Robustness						E	E	(MM)	E	E	E	E	E	E	MM	E	E	(MM)	(MM)
Volume Flexibility							E	(MM)	E	E	E	E	E	MM	MM	E	E	E	E
Routing Flexibility								E	MM	MM	MM	MM	MM	SM	SM	MM	MM	MM	MM
Topography and Topology									E	E	E	E	E	MM	MM	E	E	E	E
Community Environment										E	E	E	E	MM	MM	E	E	MM	E
Human-related Safety											E	E	MM	MM	MM	E	E	E	E
Worker-related Comfort												E	MM	MM	MM	E	E	E	E
Property-related Security													E	MM	MM	E	E	E	E
Maintenance														E	MM	(MM)	(MM)	(MM)	(MM)
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 132: Pairwise Comparison of Expert 5 with respect to Topography and Topology

Topography and Topology	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	MM	MM	MM	E	MM	MM	(SM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	E	(MM)
Inventory Cost		E	MM	MM	MM	E	MM	MM	(SM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	E	(MM)
Space Relationship			E	E	E	(MM)	E	E	(SM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	(MM)
Material Flow				E	E	(MM)	E	E	(SM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	(MM)
Non-Material Flow					E	(MM)	E	E	(SM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	(MM)
Robustness						E	MM	MM	(MM)	E	E	E	E	MM	MM	E	E	(MM)	(MM)
Volume Flexibility							E	E	(SM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	(MM)
Routing Flexibility								E	(SM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	(MM)
Topography and Topology									E	MM	MM	MM	MM	SM	SM	SM	SM	MM	MM
Community Environment										E	E	E	E	MM	MM	MM	MM	E	E
Human-related Safety											E	E	E	MM	MM	MM	MM	E	E
Worker-related Comfort												E	E	MM	MM	MM	MM	E	E
Property-related Security													E	MM	MM	MM	MM	E	E
Maintenance														E	MM	E	E	E	(MM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 133: Pairwise Comparison of Expert 5 with respect to Community Environment

Community Environment	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	MM	MM	MM	E	MM	MM	(MM)	(SM)	(MM)	(MM)	(MM)	MM	MM	E	E	E	(MM)
Inventory Cost		E	MM	MM	MM	E	MM	MM	(MM)	(SM)	(MM)	(MM)	(MM)	MM	MM	E	E	E	(MM)
Space Relationship			E	E	E	(MM)	E	E	(MM)	(SM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	(MM)
Material Flow				E	E	(MM)	E	E	(MM)	(SM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	(MM)
Non-Material Flow					E	(MM)	E	E	(MM)	(SM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	(MM)
Robustness						E	MM	MM	E	(MM)	E	E	E	MM	MM	E	E	(MM)	(MM)
Volume Flexibility							E	E	(MM)	(SM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	(MM)
Routing Flexibility								E	(MM)	(SM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	(MM)
Topography and Topology									E	(MM)	E	E	E	MM	MM	MM	MM	E	E
Community Environment										E	MM	MM	MM	SM	SM	SM	SM	MM	MM
Human-related Safety											E	E	E	MM	MM	MM	MM	E	E
Worker-related Comfort												E	E	MM	MM	MM	MM	E	E
Property-related Security													E	MM	MM	MM	MM	E	E
Maintenance														E	MM	E	E	E	(MM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 134: Pairwise Comparison of Expert 5 with respect to Human-related Safety

Human-related Safety	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	MM	E	MM	MM	(MM)	(MM)	(SM)	(MM)	E	MM	MM	E	E	E	(MM)
Inventory Cost		E	E	E	E	(MM)	E	E	(MM)	(MM)	(SM)	(MM)	(MM)	MM	MM	E	E	E	(MM)
Space Relationship			E	E	E	(MM)	E	E	(MM)	(MM)	(SM)	(MM)	(MM)	MM	MM	E	E	E	(MM)
Material Flow				E	E	(MM)	E	E	(MM)	(MM)	(SM)	(MM)	(MM)	MM	MM	E	E	E	(MM)
Non-Material Flow					E	(MM)	E	E	(SM)	(SM)	(VSM)	(SM)	(MM)	E	E	E	E	(MM)	(MM)
Robustness						E	MM	MM	E	E	(MM)	E	E	MM	MM	E	E	E	(MM)
Volume Flexibility							E	E	(MM)	(MM)	(SM)	(MM)	(MM)	MM	MM	E	E	E	(MM)
Routing Flexibility								E	(MM)	(MM)	(SM)	(MM)	(MM)	MM	MM	(MM)	(MM)	(MM)	(MM)
Topography and Topology									E	E	(MM)	E	E	MM	MM	E	E	E	(MM)
Community Environment										E	(MM)	E	E	MM	MM	E	E	E	E
Human-related Safety											E	MM	MM	SM	SM	SM	SM	MM	MM
Worker-related Comfort												E	MM	SM	SM	MM	MM	MM	MM
Property-related Security													E	MM	MM	MM	MM	E	E
Maintenance														E	MM	(MM)	(MM)	(MM)	(MM)
Sustainability															E	(MM)	(MM)	(MM)	(MM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 135: Pairwise Comparison of Expert 5 with respect Worker-related Comfort

Worker-related Comfort	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	MM	E	MM	MM	(MM)	(MM)	(MM)	(SM)	E	MM	MM	E	E	E	(MM)
Inventory Cost		E	E	E	E	(MM)	E	E	(MM)	(MM)	(MM)	(SM)	(MM)	MM	MM	E	E	E	(MM)
Space Relationship			E	E	E	(MM)	E	E	(MM)	(MM)	(MM)	(SM)	(MM)	MM	MM	E	E	E	(MM)
Material Flow				E	E	(MM)	E	E	(MM)	(MM)	(MM)	(SM)	(MM)	MM	MM	E	E	E	(MM)
Non-Material Flow					E	(MM)	E	E	(SM)	(SM)	(MM)	(SM)	(MM)	E	E	E	E	(MM)	(MM)
Robustness						E	MM	MM	E	E	E	(MM)	E	MM	MM	E	E	E	(MM)
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(SM)	(MM)	MM	MM	E	E	E	(MM)
Routing Flexibility								E	(MM)	(MM)	(MM)	(SM)	(MM)	MM	MM	(MM)	(MM)	(MM)	(MM)
Topography and Topology									E	E	E	(MM)	E	MM	MM	E	E	E	(MM)
Community Environment										E	E	(MM)	E	MM	MM	E	E	E	E
Human-related Safety											E	(MM)	E	MM	MM	MM	MM	E	E
Worker-related Comfort												E	MM	SM	SM	SM	SM	MM	MM
Property-related Security													E	MM	MM	E	E	E	E
Maintenance														E	E	E	E	(MM)	(MM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 136: Pairwise Comparison of Expert 5 with respect Property-related Security

Property-related Security	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	MM	MM	MM	MM	E	MM	MM	(MM)	(MM)	(MM)	(MM)	(SM)	MM	MM	E	E	E	(MM)
Inventory Cost		E	E	E	E	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(SM)	MM	MM	E	E	E	(MM)
Space Relationship			E	E	E	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(SM)	MM	MM	E	E	E	(MM)
Material Flow				E	E	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(SM)	MM	MM	E	E	E	(MM)
Non-Material Flow					E	(MM)	E	E	(SM)	(SM)	(MM)	(MM)	(SM)	E	E	E	E	(MM)	(MM)
Robustness						E	MM	MM	E	E	E	E	(MM)	MM	MM	E	E	E	(MM)
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(SM)	MM	MM	E	E	E	(MM)
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(SM)	MM	MM	(MM)	(MM)	(MM)	(MM)
Topography and Topology									E	E	E	E	(MM)	MM	MM	E	E	E	(MM)
Community Environment										E	E	E	(MM)	MM	MM	E	E	E	E
Human-related Safety											E	E	(MM)	MM	MM	MM	MM	E	E
Worker-related Comfort												E	(MM)	MM	MM	MM	MM	E	E
Property-related Security													E	SM	SM	SM	SM	MM	MM
Maintenance														E	MM	MM	MM	E	E
Sustainability															E	E	E	(MM)	(SM)
Time in Production																E	E	E	E
Time in non-Production																	E	E	E
Production Characteristics																		E	E
Other Characteristics																			E

Table 137: Pairwise Comparison of Expert 5 with respect Maintenance

Maintenance	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	E	E	E	E	MM	MM	E	E	E	E	E	(MM)	MM	MM	E	E	E
Inventory Cost		E	E	E	E	E	MM	MM	E	E	E	E	E	(MM)	MM	MM	E	E	E
Space Relationship			E	E	E	E	MM	MM	E	E	E	E	E	(MM)	MM	E	E	E	E
Material Flow				E	E	E	MM	MM	E	E	E	E	E	(MM)	MM	E	E	E	MM
Non-Material Flow					E	E	MM	MM	E	E	E	E	E	(MM)	MM	E	E	E	E
Robustness						E	MM	MM	E	E	E	E	E	(MM)	MM	E	E	E	MM
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(SM)	E	E	E	E	MM
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	E	(SM)	E	E	E	E	MM
Topography and Topology									E	E	E	E	E	(MM)	MM	E	E	E	MM
Community Environment										E	E	E	E	(MM)	MM	E	E	MM	MM
Human-related Safety											E	E	E	(MM)	MM	E	E	MM	MM
Worker-related Comfort												E	E	(MM)	MM	E	E	MM	MM
Property-related Security													E	(MM)	MM	E	E	MM	MM
Maintenance														E	SM	MM	MM	MM	MM
Sustainability															E	E	E	E	E
Time in Production																E	E	E	E
Time in non-Production																	E	MM	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 138: Pairwise Comparison of Expert 5 with respect Sustainability

Sustainability	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	MM	MM	MM	E	MM	MM	E	E	E	E	E	MM	(MM)	E	E	E	E
Inventory Cost		E	MM	MM	MM	E	MM	MM	E	E	E	E	E	MM	(MM)	E	E	E	E
Space Relationship			E	E	E	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	(MM)	E	(MM)	E	(MM)
Material Flow				E	E	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	(MM)	E	E	E	E
Non-Material Flow					E	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(SM)	(MM)	(MM)	(MM)	(SM)
Robustness						E	MM	MM	E	E	E	E	E	E	(MM)	E	E	E	(MM)
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	(MM)	E	E	E	(MM)
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(MM)	E	(MM)	E	E	E	(MM)
Topography and Topology									E	E	E	E	E	E	(MM)	E	E	E	E
Community Environment										E	E	E	E	E	(MM)	E	E	E	E
Human-related Safety											E	E	E	E	(MM)	E	E	E	E
Worker-related Comfort												E	E	E	(MM)	E	E	E	E
Property-related Security													E	E	(MM)	E	E	E	E
Maintenance														E	(MM)	E	E	E	(MM)
Sustainability															E	SM	SM	MM	MM
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 139: Pairwise Comparison of Expert 5 with respect Time in Production

Time in Production	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	(MM)	E	(MM)	E	E	MM	MM	E	E	E	E	E	MM	MM	(SM)	(MM)	E	E
Inventory Cost		E	MM	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	SM	SM	(MM)	E	MM	MM
Space Relationship			E	(MM)	E	E	E	E	E	E	E	E	E	MM	MM	(SM)	(MM)	E	E
Material Flow				E	MM	MM	MM	MM	E	E	E	E	E	MM	MM	(MM)	E	MM	MM
Non-Material Flow					E	E	MM	MM	E	E	E	E	E	MM	MM	(SM)	(MM)	E	E
Robustness						E	MM	MM	E	E	E	E	E	MM	MM	(SM)	(MM)	E	MM
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	(SM)	(MM)	E	E
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	(SM)	(MM)	E	E
Topography and Topology									E	E	E	E	E	MM	MM	(SM)	(MM)	E	E
Community Environment										E	E	E	E	MM	MM	(SM)	(MM)	E	E
Human-related Safety											E	E	E	MM	MM	(SM)	(MM)	E	E
Worker-related Comfort												E	E	MM	MM	(SM)	(MM)	E	E
Property-related Security													E	E	MM	(SM)	(MM)	E	E
Maintenance														E	E	(SM)	(MM)	E	E
Sustainability															E	(SM)	(MM)	(MM)	(MM)
Time in Production																E	MM	SM	SM
Time in non-Production																	E	MM	MM
Production Characteristics																		E	E
Other Characteristics																			E

Table 140: Pairwise Comparison of Expert 5 with respect Time in Non-Production

Time in non-Production	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	(MM)	E	(MM)	E	E	MM	MM	E	E	E	E	E	MM	MM	(MM)	(SM)	E	E
Inventory Cost		E	MM	E	MM	MM	MM	MM	MM	MM	MM	MM	MM	SM	SM	E	(MM)	MM	MM
Space Relationship			E	(MM)	E	E	E	E	E	E	E	E	E	MM	MM	(MM)	(SM)	E	E
Material Flow				E	MM	MM	MM	MM	E	E	E	E	E	MM	MM	E	(MM)	MM	MM
Non-Material Flow					E	E	MM	MM	E	E	E	E	E	MM	MM	(MM)	(SM)	E	E
Robustness						E	MM	MM	E	E	E	E	E	MM	MM	(MM)	(SM)	E	MM
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	(MM)	(SM)	E	E
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	(MM)	(SM)	E	E
Topography and Topology									E	E	E	E	E	MM	MM	(MM)	(SM)	E	E
Community Environment										E	E	E	E	MM	MM	(MM)	(SM)	E	E
Human-related Safety											E	E	E	MM	MM	(MM)	(SM)	E	E
Worker-related Comfort												E	E	MM	MM	(MM)	(SM)	E	E
Property-related Security													E	E	MM	(MM)	(SM)	E	E
Maintenance														E	E	(MM)	(SM)	E	E
Sustainability															E	(MM)	(SM)	(MM)	(MM)
Time in Production																E	MM	(MM)	MM
Time in non-Production																	E	SM	SM
Production Characteristics																		E	MM
Other Characteristics																			E

Table 141: Pairwise Comparison of Expert 5 with respect Production Characteristics

Production Characteristics	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	MM	MM	E	E	MM	MM	E	E	E	E	E	MM	MM	E	E	(MM)	E
Inventory Cost		E	MM	MM	E	E	MM	MM	E	E	E	E	E	MM	MM	E	E	(MM)	E
Space Relationship			E	(MM)	(MM)	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	(MM)	E
Material Flow				E	E	E	MM	MM	E	E	E	E	E	MM	MM	E	E	(MM)	E
Non-Material Flow					E	E	MM	MM	E	E	E	E	E	MM	MM	E	E	(MM)	E
Robustness						E	MM	MM	E	E	E	E	E	MM	MM	E	E	(MM)	E
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	(SM)	(MM)
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	(SM)	(MM)
Topography and Topology									E	E	E	E	MM	MM	MM	E	E	(MM)	E
Community Environment										E	E	E	MM	MM	MM	E	E	(MM)	E
Human-related Safety											E	E	MM	MM	MM	E	E	(MM)	E
Worker-related Comfort												E	MM	MM	MM	E	E	(MM)	E
Property-related Security													E	E	MM	E	E	(MM)	E
Maintenance														E	MM	(MM)	E	(SM)	(MM)
Sustainability															E	(MM)	(MM)	(SM)	(MM)
Time in Production																E	E	(MM)	E
Time in non-Production																	E	(MM)	E
Production Characteristics																		E	MM
Other Characteristics																			E

Table 142: Pairwise Comparison of Expert 5 with respect Other Characteristics

Other Characteristics	Non-Inventory Cost	Inventory Cost	Space Relationship	Material Flow	Non-Material Flow	Robustness	Volume Flexibility	Routing Flexibility	Topography and Topology	Community Environment	Human-related Safety	Worker-related Comfort	Property-related Security	Maintenance	Sustainability	Time in Production	Time in non-Production	Production Characteristics	Other Characteristics
Non-Inventory Cost	E	E	MM	MM	E	E	MM	MM	E	E	E	E	E	MM	MM	E	E	E	(MM)
Inventory Cost		E	MM	MM	E	E	MM	MM	E	E	E	E	E	MM	MM	E	E	E	(MM)
Space Relationship			E	(MM)	(MM)	(MM)	E	E	(MM)	(MM)	(MM)	(MM)	(MM)	MM	MM	E	E	E	(MM)
Material Flow				E	E	E	MM	MM	E	E	E	E	E	MM	MM	E	E	E	(MM)
Non-Material Flow					E	E	MM	MM	E	E	E	E	E	MM	MM	E	E	E	(MM)
Robustness						E	MM	MM	E	E	E	E	E	MM	MM	E	E	E	(MM)
Volume Flexibility							E	E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	(MM)	(SM)
Routing Flexibility								E	(MM)	(MM)	(MM)	(MM)	(MM)	E	E	E	E	(MM)	(SM)
Topography and Topology									E	E	E	E	MM	MM	MM	E	E	E	(MM)
Community Environment										E	E	E	MM	MM	MM	E	E	E	(MM)
Human-related Safety											E	E	MM	MM	MM	E	E	E	(MM)
Worker-related Comfort												E	MM	MM	MM	E	E	E	(MM)
Property-related Security													E	E	MM	E	E	(MM)	(MM)
Maintenance														E	MM	(MM)	E	(MM)	(SM)
Sustainability															E	(MM)	(MM)	(MM)	(SM)
Time in Production																E	E	E	(MM)
Time in non-Production																	E	E	(MM)
Production Characteristics																		E	(MM)
Other Characteristics																			E

Table 143: Pairwise Comparison of Expert 2 with respect to Non-Inventory Cost

Non-Inventory Cost	Land Cost	Building Cost	Machinery Cost	Material Handling Cost	Labor Cost	Maintenance Cost	Future Salvage Value	Quality Cost	Capital Cost of MHE	Rearrangement Cost	Setup Cost	Energy Cost	Safety Cost	Manufacturing Operation Cost
Land Cost	E	MM	E	(SM)	MM	SM	SM	SM	E	(MM)	MM	SM	MM	(SM)
Building Cost		E	(MM)	(VSM)	E	MM	MM	MM	(MM)	(SM)	E	MM	E	(VSM)
Machinery Cost			E	(SM)	MM	SM	SM	SM	E	(MM)	MM	SM	MM	(SM)
Material Handling Cost				E	VSM	EM	EM	EM	SM	MM	SM	VSM	SM	E
Labor Cost					E	MM	MM	MM	(MM)	(SM)	MM	MM	E	(VSM)
Maintenance Cost						E	E	E	(SM)	(VSM)	E	MM	MM	(VSM)
Future Salvage Value							E	E	(SM)	(VSM)	(MM)	E	E	(VSM)
Quality Cost								E	(MM)	(SM)	E	MM	E	(VSM)
Capital Cost of MHE									E	(MM)	MM	MM	MM	(SM)
Rearrangement Cost										E	SM	SM	SM	(MM)
Setup Cost											E	E	E	(SM)
Energy Cost												E	E	(SM)
Safety Cost													E	(SM)
Manufacturing Operation Cost														E

Table 144: Pairwise Comparison of Expert 2 with respect to Inventory Cost

Inventory Cost	Raw Material Inventory Holding Cost	WIP Inventory Holding Cost	Finished Goods Inventory Holding Cost	Backordering Cost	Loss
Raw Material Inventory Holding Cost	E	E	SM	E	E
WIP Inventory Holding Cost		E	SM	E	E
Finished Goods Inventory Holding Cost			E	(SM)	(SM)
Backordering Cost				E	E
Loss					E

Table 145: Pairwise Comparison of Expert 2 with respect to Space Relationship

Space Relationship	Value-Added Area	Non-Value-Added Area	Storage Space	Dead Space	Required Area	Space Efficiency	Space Utilization
Value-Added Area	E	VSM	MM	SM	MM	MM	MM
Non-Value-Added Area		E	(SM)	(MM)	(SM)	(SM)	(SM)
Storage Space			E	MM	E	E	E
Dead Space				E	(MM)	(SM)	(SM)
Required Area					E	(MM)	(MM)
Space Efficiency						E	E
Space Utilization							E

Table 146: Pairwise Comparison of Expert 2 with respect to Material Flow

Material Flow	Volume	Dimensions of the Aisles	Number of Loaded Travel of MHE	Number of Empty Travel of MHE	Adjacency Score	Speed	Intermodule Distances	Accessibility	Aspect Ratio	Interferences (Overlapping)
Volume	E	VSM	MM	VSM	MM	SM	E	SM	VSM	VSM
Dimensions of the Aisles		E	(SM)	E	(SM)	(MM)	(VSM)	(MM)	E	MM
Number of Loaded Travel of MHE			E	SM	E	MM	(SM)	MM	SM	SM
Number of Empty Travel of MHE				E	(SM)	(SM)	(EM	(MM)	E	E
Adjacency Score					E	MM	(MM)	MM	SM	SM
Speed						E	(SM)	MM	SM	SM
Intermodule Distances							E	SM	VSM	VSM
Accessibility								E	E	MM
Aspect Ratio									E	MM
Interferences (Overlapping)										E

Table 147: Pairwise Comparison of Expert 2 with respect to Non-Material Flow

Non-Material Flow	Information Flow (Frequency)	Personnel Flow (Frequency)	Equipment Flow (Frequency)
Information Flow (Frequency)	E	MM	MM
Personnel Flow (Frequency)		E	E
Equipment Flow (Frequency)			E

Table 148: Pairwise Comparison of Expert 2 with respect to Robustness

Robustness	Robustness of Equipment	Building Expansion	Free Space Availability
Robustness of Equipment	E	E	MM
Building Expansion		E	MM
Free Space Availability			E

Table 149: Pairwise Comparison of Expert 2 with respect to Volume Flexibility

Volume Flexibility	Adaptation to Variations in Production Volume	Adaptation to Variations in Demand Volume	Adaptation to Variations in Material Handling Cost	Adaptation to Variations in Material Flow	Adaptation to Variations in Equipment	Adaptation to Variations in Technology	Adaptation to Variations in Product Mix	Adaptation to Variations in Order Arrival Time	Adaptation to Variations in Processing Requirements	Adaptation to Variations in Due Date Requirements	Adaptation to Variations in Processing Time
Adaptation to Variations in Production Volume	E	MM	MM	MM	SM	MM	MM	SM	SM	SM	MM
Adaptation to Variations in Demand Volume		E	E	E	MM	E	E	MM	MM	MM	E
Adaptation to Variations in Material Handling Cost			E	E	MM	E	E	MM	MM	MM	E
Adaptation to Variations in Material Flow				E	MM	E	E	MM	MM	MM	2.00
Adaptation to Variations in Equipment					E	(MM)	(MM)	E	E	E	(MM)
Adaptation to Variations in Technology						E	E	MM	MM	MM	E
Adaptation to Variations in Product Mix							E	MM	MM	MM	E
Adaptation to Variations in Order Arrival Time								E	E	E	(MM)
Adaptation to Variations in Processing Requirements									E	E	(MM)
Adaptation to Variations in Due Date Requirements										E	(MM)
Adaptation to Variations in Processing Time											E

Table 150: Pairwise Comparison of Expert 2 with respect to Routing Flexibility

Routing Flexibility	Average Number of Alternate Routes	Accessibility of Alternate Routes
Average Number of Alternate Routes	E	MM
Accessibility of Alternate Routes		E

Table 151: Pairwise Comparison of Expert 2 with respect to Topography and Topology

Topography and Topology	Natural Site Conditions and Construction	Truck Access and Circulation Pattern	Connection with External MHE
Natural Site Conditions and Construction	E	E	E
Truck Access and Circulation Pattern		E	E
Connection with External MHE			E

Table 152: Pairwise Comparison of Expert 2 with respect to Community Environment

Community Environment	Impact of Traffic Congestion and Noise	Waste Management and Pollution Control	Appearance of External or Viewable Features
Impact of Traffic Congestion and Noise	E	E	MM
Waste Management and Pollution Control		E	MM
Appearance of External or Viewable Features			E

Table 153: Pairwise Comparison of Expert 2 with respect to Human-related Safety

Human-related Safety	Human Building Accidents	Human Vehicle Crossings	Human/Machine/Material/Material Handling Interfaces	Fire / Earthquake / Evacuation
Human Building Accidents	E	MM	MM	MM
Human Vehicle Crossings		E	E	E
Human/Machine/Material/Material Handling Interfaces			E	E
Fire / Earthquake / Evacuation				E

Table 154: Pairwise Comparison of Expert 2 with respect to Worker-related Comfort

Worker-related Comfort	Lighting	Aesthetics	Ease of Supervision	Noise	Ventilation / Heating	Ergonomics	Handicapped Access	Employee Satisfaction	Hygiene	Humidity	Pressure	Signs and Artifacts
Lighting	E	MM	E	E	E	E	E	E	E	E	E	E
Aesthetics		E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Ease of Supervision			E	MM	MM	E	MM	E	E	MM	MM	E
Noise				E	E	E	MM	(MM)	E	MM	MM	E
Ventilation / Heating					E	(MM)	E	(MM)	E	MM	MM	E
Ergonomics						E	MM	E	MM	MM	MM	E
Handicapped Access							E	(MM)	E	E	E	E
Employee Satisfaction								E	MM	MM	MM	E
Hygiene									E	E	E	(MM)
Humidity										E	E	E
Pressure											E	E
Signs and Artifacts												E

Table 155: Pairwise Comparison of Expert 2 with respect to Property-related Security

Property-related Security	Theft from outside the Building	Theft from within the Building	Special Caution for Dangerous Areas
Theft from outside the Building	E	E	E
Theft from within the Building		E	E
Special Caution for Dangerous Areas			E

Table 156: Pairwise Comparison of Expert 2 with respect to Maintenance

Maintenance	Compatibility of Building Construction and MHE	Space for Maintenance Work	Appropriate Location of Maintenance Activities	Complexity of MHE
Compatibility of Building Construction and MHE	E	MM	MM	MM
Space for Maintenance Work		E	E	E
Appropriate Location of Maintenance Activities			E	E
Complexity of MHE				E

Table 157: Pairwise Comparison of Expert 2 with respect to Sustainability

Sustainability	Number of Reused / Recycled Materials	Environmental Sustainability Index	Environmental Performance Index
Number of Reused / Recycled Materials	E	(MM)	(SM)
Environmental Sustainability Index		E	(MM)
Environmental Performance Index			E

Table 158: Pairwise Comparison of Expert 2 with respect to Time in Production

Time in Production	Production Time	Setup Time	Throughput Time	Overall Processing Time	Cycle Time	Idle Time
Production Time	E	SM	MM	E	MM	SM
Setup Time		E	(MM)	(SM)	(MM)	E
Throughput Time			E	(MM)	E	MM
Overall Processing Time				E	MM	SM
Cycle Time					E	MM
Idle Time						E

Table 159: Pairwise Comparison of Expert 2 with respect to Time in non-Production

Time in Non-Production	Storage Time	Retrieval Time	Loading Time	Unloading Time	Stoppages	Transportation Time
Storage Time	E	E	E	E	MM	(MM)
Retrieval Time		E	E	E	MM	(MM)
Loading Time			E	E	MM	(MM)
Unloading Time				E	MM	(MM)
Stoppages					E	(SM)
Transportation Time						E

Table 160: Pairwise Comparison of Expert 2 with respect to Production Characteristics

Production Characteristics	Production Volume	Production / Machine Capacity	Total Quality Management (Kaizen)	Quality of the Product	Raw Material Inventory	WIP Inventory	Finished Goods Inventory
Production Volume	E	E	MM	E	E	MM	MM
Production / Machine Capacity		E	MM	E	E	MM	MM
Total Quality Management (Kaizen)			E	(MM)	(MM)	E	E
Quality of the Product				E	E	MM	MM
Raw Material Inventory					E	MM	MM
WIP Inventory						E	E
Finished Goods Inventory							E

Table 161: Pairwise Comparison of Expert 2 with respect to Other Characteristics

Other Characteristics	Average Machine Utilization	Size	Shape of Departments	Shape of Machines	Number of Departments	Number of Machines	Average Availability of Facilities	Manpower Requirements (Skills, Qualifications)
Average Machine Utilization	E	MM	MM	MM	MM	MM	E	MM
Size		E	E	E	E	E	(MM)	(MM)
Shape of Departments			E	E	E	E	(MM)	E
Shape of Machines				E	E	E	(MM)	(MM)
Number of Departments					E	E	(MM)	E
Number of Machines						E	(MM)	E
Average Availability of Facilities							E	MM
Manpower Requirements (Skills, Qualifications)								E

Table 162: Pairwise Comparison of Expert 3 with respect to Non-Inventory Cost

Non-Inventory Cost	Land Cost	Building Cost	Machinery Cost	Material Handling Cost	Labor Cost	Maintenance Cost	Future Salvage Value	Quality Cost	Capital Cost of MHE	Rearrangement Cost	Setup Cost	Energy Cost	Safety Cost	Manufacturing Operation Cost
Land Cost	E	E	(MM)	(SM)	E	MM	MM	MM	(MM)	(MM)	MM	MM	SM	(SM)
Building Cost		E	E	(SM)	MM	MM	SM	MM	(MM)	(MM)	MM	MM	MM	(SM)
Machinery Cost			E	(SM)	E	MM	MM	MM	(MM)	(MM)	E	MM	MM	(SM)
Material Handling Cost				E	VSM	VSM	VSM	VSM	MM	MM	VSM	VSM	VSM	E
Labor Cost					E	E	MM	E	(MM)	(SM)	MM	MM	MM	(VSM)
Maintenance Cost						E	MM	E	(MM)	(SM)	MM	MM	MM	(VSM)
Future Salvage Value							E	(MM)	(MM)	(SM)	(MM)	E	E	(VSM)
Quality Cost								E	E	(MM)	E	MM	MM	(SM)
Capital Cost of MHE									E	E	MM	MM	MM	(SM)
Rearrangement Cost										E	MM	SM	SM	(MM)
Setup Cost											E	(MM)	E	(SM)
Energy Cost												E	MM	(SM)
Safety Cost													E	(SM)
Manufacturing Operation Cost														E

Table 163: Pairwise Comparison of Expert 3 with respect to Inventory Cost

Inventory Cost	Raw Material Inventory Holding Cost	WIP Inventory Holding Cost	Finished Goods Inventory Holding Cost	Backordering Cost	Loss
Raw Material Inventory Holding Cost	E	SM	SM	SM	SM
WIP Inventory Holding Cost		E	MM	E	MM
Finished Goods Inventory Holding Cost			E	(SM)	E
Backordering Cost				E	MM
Loss					E

Table 164: Pairwise Comparison of Expert 3 with respect to Space Relationship

Space Relationship	Value-Added Area	Non-Value-Added Area	Storage Space	Dead Space	Required Area	Space Efficiency	Space Utilization
Value-Added Area	E	EM	SM	VSM	SM	MM	MM
Non-Value-Added Area		E	(SM)	(MM)	(SM)	(VSM)	(VSM)
Storage Space			E	MM	E	(MM)	(MM)
Dead Space				E	(MM)	(SM)	(SM)
Required Area					E	(MM)	(MM)
Space Efficiency						E	E
Space Utilization							E

Table 165: Pairwise Comparison of Expert 3 with respect to Material Flow

Material Flow	Volume	Dimensions of the Aisles	Number of Loaded Travel of MHE	Number of Empty Travel of MHE	Adjacency Score	Speed	Intermodule Distances	Accessibility	Aspect Ratio	Interferences (Overlapping)
Volume	E	SM	SM	SM	MM	MM	E	SM	MM	SM
Dimensions of the Aisles		E	E	E	(MM)	(MM)	(SM)	E	(MM)	E
Number of Loaded Travel of MHE			E	MM	(MM)	E	(SM)	MM	E	MM
Number of Empty Travel of MHE				E	(SM)	(SM)	(VSM)	(MM)	(MM)	(MM)
Adjacency Score					E	E	(MM)	MM	SM	SM
Speed						E	(MM)	MM	SM	SM
Intermodule Distances							E	VSM	SM	MM
Accessibility								E	E	E
Aspect Ratio									E	(MM)
Interferences (Overlapping)										E

Table 166: Pairwise Comparison of Expert 3 with respect to Non-Material Flow

Non-Material Flow	Information Flow (Frequency)	Personnel Flow (Frequency)	Equipment Flow (Frequency)
Information Flow (Frequency)	E	E	MM
Personnel Flow (Frequency)		E	MM
Equipment Flow (Frequency)			E

Table 167: Pairwise Comparison of Expert 3 with respect to Robustness

Robustness	Robustness of Equipment	Building Expansion	Free Space Availability
Robustness of Equipment	E	MM	E
Building Expansion		E	(MM)
Free Space Availability			E

Table 168: Pairwise Comparison of Expert 3 with respect to Volume Flexibility

Volume Flexibility	Adaptation to Variations in Production Volume	Adaptation to Variations in Demand Volume	Adaptation to Variations in Material Handling Cost	Adaptation to Variations in Material Flow	Adaptation to Variations in Equipment	Adaptation to Variations in Technology	Adaptation to Variations in Product Mix	Adaptation to Variations in Order Arrival Time	Adaptation to Variations in Processing Requirements	Adaptation to Variations in Due Date Requirements	Adaptation to Variations in Processing Time
Adaptation to Variations in Production Volume	E	E	E	E	E	E	E	E	E	E	E
Adaptation to Variations in Demand Volume		E	E	E	E	E	E	E	E	E	E
Adaptation to Variations in Material Handling Cost			E	E	E	E	E	E	E	E	E
Adaptation to Variations in Material Flow				E	E	E	E	E	E	E	E
Adaptation to Variations in Equipment					E	E	E	E	E	E	E
Adaptation to Variations in Technology						E	E	E	E	E	E
Adaptation to Variations in Product Mix							E	E	E	E	E
Adaptation to Variations in Order Arrival Time								E	E	E	E
Adaptation to Variations in Processing Requirements									E	E	E
Adaptation to Variations in Due Date Requirements										E	E
Adaptation to Variations in Processing Time											E

Table 169: Pairwise Comparison of Expert 3 with respect to Routing Flexibility

Routing Flexibility	Average Number of Alternate Routes	Accessibility of Alternate Routes
Average Number of Alternate Routes	E	(MM)
Accessibility of Alternate Routes		E

Table 170: Pairwise Comparison of Expert 3 with respect to Topography and Topology

Topography and Topology	Natural Site Conditions and Construction	Truck Access and Circulation Pattern	Connection with External MHE
Natural Site Conditions and Construction	E	E	(MM)
Truck Access and Circulation Pattern		E	(MM)
Connection with External MHE			E

Table 171: Pairwise Comparison of Expert 3 with respect to Community Environment

Community Environment	Impact of Traffic Congestion and Noise	Waste Management and Pollution Control	Appearance of External or Viewable Features
Impact of Traffic Congestion and Noise	E	E	E
Waste Management and Pollution Control		E	E
Appearance of External or Viewable Features			E

Table 172: Pairwise Comparison of Expert 3 with respect to Human-related Safety

Human-related Safety	Human Building Accidents	Human Vehicle Crossings	Human/Machine/Material/Material Handling Interfaces	Fire / Earthquake / Evacuation
Human Building Accidents	E	E	(MM)	(MM)
Human Vehicle Crossings		E	(MM)	(MM)
Human/Machine/Material/Material Handling Interfaces			E	E
Fire / Earthquake / Evacuation				E

Table 173: Pairwise Comparison of Expert 3 with respect to Worker-related Comfort

Worker-related Comfort	Lighting	Aesthetics	Ease of Supervision	Noise	Ventilation / Heating	Ergonomics	Handicapped Access	Employee Satisfaction	Hygiene	Humidity	Pressure	Signs and Artifacts
Lighting	E	MM	(MM)	(MM)	E	(MM)	MM	(MM)	E	MM	MM	E
Aesthetics		E	(SM)	(MM)	E	(MM)	E	(SM)	(MM)	E	E	(MM)
Ease of Supervision			E	E	MM	E	MM	E	MM	MM	MM	E
Noise				E	MM	E	MM	(MM)	E	MM	MM	E
Ventilation / Heating					E	(MM)	E	(MM)	E	E	E	(MM)
Ergonomics						E	MM	E	E	MM	MM	E
Handicapped Access							E	(MM)	(MM)	E	E	(MM)
Employee Satisfaction								E	MM	MM	MM	E
Hygiene									E	MM	MM	E
Humidity										E	E	(MM)
Pressure											E	(MM)
Signs and Artifacts												E

Table 174: Pairwise Comparison of Expert 3 with respect to Property-related Security

Property-related Security	Theft from outside the Building	Theft from within the Building	Special Caution for Dangerous Areas
Theft from outside the Building	E	E	(MM)
Theft from within the Building		E	(MM)
Special Caution for Dangerous Areas			E

Table 175: Pairwise Comparison of Expert 3 with respect to Maintenance

Maintenance	Compatibility of Building Construction and MHE	Space for Maintenance Work	Appropriate Location of Maintenance Activities	Complexity of MHE
Compatibility of Building Construction and MHE	E	MM	E	MM
Space for Maintenance Work		E	(MM)	E
Appropriate Location of Maintenance Activities			E	E

Table 176: Pairwise Comparison of Expert 3 with respect to Sustainability

Sustainability	Number of Reused / Recycled Materials	Environmental Sustainability Index	Environmental Performance Index
Number of Reused / Recycled Materials	E	E	E
Environmental Sustainability Index		E	E
Environmental Performance Index			E

Table 177: Pairwise Comparison of Expert 3 with respect to Time in Production

Time in Production	Production Time	Setup Time	Throughput Time	Overall Processing Time	Cycle Time	Idle Time
Production Time	E	MM	MM	E	MM	MM
Setup Time		E	E	(MM)	E	E
Throughput Time			E	(MM)	E	E
Overall Processing Time				E	MM	MM
Cycle Time					E	E
Idle Time						E

Table 178: Pairwise Comparison of Expert 3 with respect to Time in non-Production

Time in Non-Production	Storage Time	Retrieval Time	Loading Time	Unloading Time	Stoppages	Transportation Time
Storage Time	E	E	(MM)	(MM)	MM	(MM)
Retrieval Time		E	(MM)	(MM)	E	(MM)
Loading Time			E	E	MM	E
Unloading Time				E	MM	E
Stoppages					E	(MM)
Transportation Time						E

Table 179: Pairwise Comparison of Expert 3 with respect to Production Characteristics

Production Characteristics	Production Volume	Production / Machine Capacity	Total Quality Management (Kaizen)	Quality of the Product	Raw Material Inventory	WIP Inventory	Finished Goods Inventory
Production Volume	E	E	MM	E	E	E	MM
Production / Machine Capacity		E	MM	E	E	E	MM
Total Quality Management (Kaizen)			E	(MM)	(MM)	(MM)	E
Quality of the Product				E	E	E	MM
Raw Material Inventory					E	E	MM
WIP Inventory						E	E
Finished Goods Inventory							E

Table 180: Pairwise Comparison of Expert 3 with respect to Other Characteristics

Other Characteristics	Average Machine Utilization	Size	Shape of Departments	Shape of Machines	Number of Departments	Number of Machines	Average Availability of Facilities	Manpower Requirements (Skills, Qualifications)
Average Machine Utilization	E	SM	MM	MM	MM	MM	E	MM
Size		E	(MM)	(MM)	(MM)	(MM)	(SM)	(MM)
Shape of Departments			E	E	E	E	(MM)	E
Shape of Machines				E	E	E	(MM)	E
Number of Departments					E	E	(MM)	E
Number of Machines						E	(MM)	E
Average Availability of Facilities							E	MM
Manpower Requirements (Skills, Qualifications)								E

Table 181: Pairwise Comparison of Expert 4 with respect to Non-Inventory Cost

Non-Inventory Cost	Land Cost	Building Cost	Machinery Cost	Material Handling Cost	Labor Cost	Maintenance Cost	Future Salvage Value	Quality Cost	Capital Cost of MHE	Rearrangement Cost	Setup Cost	Energy Cost	Safety Cost	Manufacturing Operation Cost
Land Cost	E	E	MM	(SM)	MM	MM	MM	MM	(MM)	(MM)	SM	SM	SM	(SM)
Building Cost		E	MM	(SM)	MM	MM	MM	MM	(MM)	(MM)	MM	MM	MM	(SM)
Machinery Cost			E	(SM)	E	E	E	E	(MM)	(MM)	E	E	E	(SM)
Material Handling Cost				E	SM	VSM	VSM	VSM	MM	MM	VSM	VSM	VSM	(MM)
Labor Cost					E	E	MM	E	(MM)	(SM)	E	MM	MM	(VSM)
Maintenance Cost						E	MM	E	(MM)	(SM)	MM	MM	MM	(SM)
Future Salvage Value							E	(MM)	(SM)	(VSM)	(MM)	(MM)	(MM)	(VSM)
Quality Cost								E	(MM)	(MM)	MM	MM	MM	(SM)
Capital Cost of MHE									E	E	SM	SM	SM	(SM)
Rearrangement Cost										E	SM	SM	SM	(SM)
Setup Cost											E	MM	MM	(SM)
Energy Cost												E	MM	(SM)
Safety Cost													E	(SM)
Manufacturing Operation Cost														E

Table 182: Pairwise Comparison of Expert 4 with respect to Inventory Cost

Inventory Cost	Raw Material Inventory Holding Cost	WIP Inventory Holding Cost	Finished Goods Inventory Holding Cost	Backordering Cost	Loss
Raw Material Inventory Holding Cost	E	E	MM	MM	MM
WIP Inventory Holding Cost		E	MM	MM	MM
Finished Goods Inventory Holding Cost			E	E	E
Backordering Cost				E	E
Loss					E

Table 183: Pairwise Comparison of Expert 4 with respect to Space Relationship

Space Relationship	Value-Added Area	Non-Value-Added Area	Storage Space	Dead Space	Required Area	Space Efficiency	Space Utilization
Value-Added Area	E	SM	MM	SM	MM	MM	MM
Non-Value-Added Area		E	(MM)	E	(MM)	(MM)	(MM)
Storage Space			E	MM	E	E	E
Dead Space				E	(MM)	(MM)	(MM)
Required Area					E	(MM)	(MM)
Space Efficiency						E	(MM)
Space Utilization							E

Table 184: Pairwise Comparison of Expert 4 with respect to Material Flow

Material Flow	Volume	Dimensions of the Aisles	Number of Loaded Travel of MHE	Number of Empty Travel of MHE	Adjacency Score	Speed	Intermodule Distances	Accessibility	Aspect Ratio	Interferences (Overlapping)
Volume	E	SM	MM	VSM	E	E	(MM)	SM	MM	MM
Dimensions of the Aisles		E	(MM)	MM	(SM)	(SM)	(VSM)	E	(MM)	E
Number of Loaded Travel of MHE			E	MM	E	(MM)	(SM)	MM	MM	E
Number of Empty Travel of MHE				E	(SM)	(MM)	(SM)	(MM)	(MM)	(MM)
Adjacency Score					E	E	(MM)	MM	MM	MM
Speed						E	(MM)	MM	MM	E
Intermodule Distances							E	SM	VSM	SM
Accessibility								E	E	E
Aspect Ratio									E	E
Interferences (Overlapping)										E

Table 185: Pairwise Comparison of Expert 4 with respect to Non-Material Flow

Non-Material Flow	Information Flow (Frequency)	Personnel Flow (Frequency)	Equipment Flow (Frequency)
Information Flow (Frequency)	E	(MM)	(MM)
Personnel Flow (Frequency)		E	(MM)
Equipment Flow (Frequency)			E

Table 186: Pairwise Comparison of Expert 4 with respect to Robustness

Robustness	Robustness of Equipment	Building Expansion	Free Space Availability
Robustness of Equipment	E	E	E
Building Expansion		E	E
Free Space Availability			E

Table 187: Pairwise Comparison of Expert 4 with respect to Volume Flexibility

Volume Flexibility	Adaptation to Variations in Production Volume	Adaptation to Variations in Demand Volume	Adaptation to Variations in Material Handling Cost	Adaptation to Variations in Material Flow	Adaptation to Variations in Equipment	Adaptation to Variations in Technology	Adaptation to Variations in Product Mix	Adaptation to Variations in Order Arrival Time	Adaptation to Variations in Processing Requirements	Adaptation to Variations in Due Date Requirements	Adaptation to Variations in Processing Time
Adaptation to Variations in Production Volume	E	(MM)	E	MM	E	E	(MM)	MM	MM	MM	MM
Adaptation to Variations in Demand Volume		E	MM	SM	MM	MM	E	SM	SM	SM	SM
Adaptation to Variations in Material Handling Cost			E	MM	E	E	(MM)	MM	MM	MM	MM
Adaptation to Variations in Material Flow				E	(MM)	(MM)	(SM)	E	E	E	E
Adaptation to Variations in Equipment					E	(MM)	(MM)	MM	MM	MM	MM
Adaptation to Variations in Technology						E	(MM)	MM	MM	MM	MM
Adaptation to Variations in Product Mix							E	SM	SM	SM	SM
Adaptation to Variations in Order Arrival Time								E	E	E	E
Adaptation to Variations in Processing Requirements									E	E	(MM)
Adaptation to Variations in Due Date Requirements										E	E
Adaptation to Variations in Processing Time											E

Table 188: Pairwise Comparison of Expert 4 with respect to Routing Flexibility

Routing Flexibility	Average Number of Alternate Routes	Accessibility of Alternate Routes
Average Number of Alternate Routes	E	E
Accessibility of Alternate Routes		E

Table 189: Pairwise Comparison of Expert 4 with respect to Topography and Topology

Topography and Topology	Natural Site Conditions and Construction	Truck Access and Circulation Pattern	Connection with External MHE
Natural Site Conditions and Construction	E	MM	E
Truck Access and Circulation Pattern		E	E
Connection with External MHE			E

Table 190: Pairwise Comparison of Expert 4 with respect to Community Environment

Community Environment	Impact of Traffic Congestion and Noise	Waste Management and Pollution Control	Appearance of External or Viewable Features
Impact of Traffic Congestion and Noise	E	(MM)	E
Waste Management and Pollution Control		E	(MM)
Appearance of External or Viewable Features			E

Table 191: Pairwise Comparison of Expert 4 with respect to Human-related Safety

Human-related Safety	Human Building Accidents	Human Vehicle Crossings	Human/Machine/Material/Material Handling Interfaces	Fire / Earthquake / Evacuation
Human Building Accidents	E	MM	E	E
Human Vehicle Crossings		E	(MM)	(MM)
Human/Machine/Material/Material Handling Interfaces			E	E
Fire / Earthquake / Evacuation				E

Table 192: Pairwise Comparison of Expert 4 with respect to Worker-related Comfort

Worker-related Comfort	Lighting	Aesthetics	Ease of Supervision	Noise	Ventilation / Heating	Ergonomics	Handicapped Access	Employee Satisfaction	Hygiene	Humidity	Pressure	Signs and Artifacts
Lighting	E	MM	(MM)	E	E	(MM)	MM	(MM)	E	MM	MM	E
Aesthetics		E	(SM)	(MM)	(MM)	(SM)	E	(SM)	(MM)	E	E	(MM)
Ease of Supervision			E	MM	MM	E	SM	E	MM	SM	SM	E
Noise				E	E	(MM)	MM	(MM)	E	MM	MM	E
Ventilation / Heating					E	(MM)	MM	(MM)	(MM)	E	E	E
Ergonomics						E	MM	E	MM	SM	MM	E
Handicapped Access							E	(MM)	(MM)	E	E	(MM)
Employee Satisfaction								E	MM	SM	SM	E
Hygiene									E	MM	E	E
Humidity										E	E	E
Pressure											E	E
Signs and Artifacts												E

Table 193: Pairwise Comparison of Expert 4 with respect to Property-related Security

Property-related Security	Theft from outside the Building	Theft from within the Building	Special Caution for Dangerous Areas
Theft from outside the Building	E	MM	E
Theft from within the Building		E	(MM)
Special Caution for Dangerous Areas			E

Table 194: Pairwise Comparison of Expert 4 with respect to Maintenance

Maintenance	Compatibility of Building Construction and MHE	Space for Maintenance Work	Appropriate Location of Maintenance Activities	Complexity of MHE
Compatibility of Building Construction and MHE	E	E	E	E
Space for Maintenance Work		E	E	E
Appropriate Location of Maintenance Activities			E	E
Complexity of MHE				E

Table 195: Pairwise Comparison of Expert 4 with respect to Sustainability

Sustainability	Number of Reused / Recycled Materials	Environmental Sustainability Index	Environmental Performance Index
Number of Reused / Recycled Materials	E	E	E
Environmental Sustainability Index		E	E
Environmental Performance Index			E

Table 196: Pairwise Comparison of Expert 4 with respect to Time in Production

Time in Production	Production Time	Setup Time	Throughput Time	Overall Processing Time	Cycle Time	Idle Time
Production Time	E	MM	E	E	MM	MM
Setup Time		E	(MM)	(MM)	E	E
Throughput Time			E	E	MM	MM
Overall Processing Time				E	MM	MM
Cycle Time					E	E
Idle Time						E

Table 197: Pairwise Comparison of Expert 4 with respect to Time in non-Production

Time in Non-Production	Storage Time	Retrieval Time	Loading Time	Unloading Time	Stoppages	Transportation Time
Storage Time	E	E	E	E	MM	(MM)
Retrieval Time		E	(MM)	(MM)	MM	(MM)
Loading Time			E	E	MM	(MM)
Unloading Time				E	MM	(MM)
Stoppages					E	(MM)
Transportation Time						E

Table 198: Pairwise Comparison of Expert 4 with respect to Production Characteristics

Production Characteristics	Production Volume	Production / Machine Capacity	Total Quality Management (Kaizen)	Quality of the Product	Raw Material Inventory	WIP Inventory	Finished Goods Inventory
Production Volume	E	E	SM	E	E	MM	SM
Production / Machine Capacity		E	SM	E	E	MM	SM
Total Quality Management (Kaizen)			E	(SM)	(SM)	(MM)	E
Quality of the Product				E	E	MM	SM
Raw Material Inventory					E	MM	SM
WIP Inventory						E	MM
Finished Goods Inventory							E

Table199: Pairwise Comparison of Expert 4 with respect to Other Characteristics

Other Characteristics	Average Machine Utilization	Size	Shape of Departments	Shape of Machines	Number of Departments	Number of Machines	Average Availability of Facilities	Manpower Requirements (Skills, Qualifications)
Average Machine Utilization	E	SM	MM	MM	MM	MM	E	MM
Size		E	(MM)	(MM)	(MM)	(MM)	(SM)	(MM)
Shape of Departments			E	E	E	E	(MM)	E
Shape of Machines				E	E	E	(MM)	E
Number of Departments					E	E	(MM)	E
Number of Machines						E	(MM)	E
Average Availability of Facilities							E	E
Manpower Requirements (Skills, Qualifications)								E

Table 200: Pairwise Comparison of Expert 5 with respect to Non-Inventory Cost

Non-Inventory Cost	Land Cost	Building Cost	Machinery Cost	Material Handling Cost	Labor Cost	Maintenance Cost	Future Salvage Value	Quality Cost	Capital Cost of MHE	Rearrangement Cost	Setup Cost	Energy Cost	Safety Cost	Manufacturing Operation Cost
Land Cost	E	MM	MM	(SM)	SM	MM	SM	MM	E	E	SM	SM	SM	(SM)
Building Cost		E	E	(SM)	MM	E	MM	E	(MM)	(MM)	MM	MM	MM	(SM)
Machinery Cost			E	(SM)	MM	E	MM	E	(MM)	(MM)	MM	MM	MM	(SM)
Material Handling Cost				E	SM	VSM	VSM	VSM	MM	MM	VSM	VSM	VSM	E
Labor Cost					E	(MM)	MM	E	(MM)	(SM)	E	E	E	(VSM)
Maintenance Cost						E	MM	E	(SM)	(VSM)	MM	MM	MM	(VSM)
Future Salvage Value							E	(MM)	(SM)	(VSM)	E	E	E	(VSM)
Quality Cost								E	(MM)	(MM)	MM	MM	MM	(SM)
Capital Cost of MHE									E	E	SM	SM	SM	(SM)
Rearrangement Cost										E	SM	SM	SM	(SM)
Setup Cost											E	(MM)	E	(VSM)
Energy Cost												E	MM	(SM)
Safety Cost													E	(VSM)
Manufacturing Operation Cost														E

Table 201: Pairwise Comparison of Expert 5 with respect to Inventory Cost

Inventory Cost	Raw Material Inventory Holding Cost	WIP Inventory Holding Cost	Finished Goods Inventory Holding Cost	Backordering Cost	Loss
Raw Material Inventory Holding Cost	E	E	SM	SM	SM
WIP Inventory Holding Cost		E	SM	SM	SM
Finished Goods Inventory Holding Cost			E	E	E
Backordering Cost				E	E
Loss					E

Table 202: Pairwise Comparison of Expert 5 with respect to Space Relationship

Space Relationship	Value-Added Area	Non-Value-Added Area	Storage Space	Dead Space	Required Area	Space Efficiency	Space Utilization
Value-Added Area	E	VSM	SM	VSM	SM	MM	MM
Non-Value-Added Area		E	(MM)	E	(MM)	(SM)	(SM)
Storage Space			E	MM	E	(MM)	(MM)
Dead Space				E	(MM)	(SM)	(SM)
Required Area					E	(MM)	(MM)
Space Efficiency						E	E
Space Utilization							E

Table 203: Pairwise Comparison of Expert 5 with respect to Material Flow

Material Flow	Volume	Dimensions of the Aisles	Number of Loaded Travel of MHE	Number of Empty Travel of MHE	Adjacency Score	Speed	Intermodule Distances	Accessibility	Aspect Ratio	Interferences (Overlapping)
Volume	E	MM	E	SM	E	E	E	MM	MM	E
Dimensions of the Aisles		E	(MM)	MM	(MM)	(MM)	(MM)	E	E	E
Number of Loaded Travel of MHE			E	SM	E	E	E	MM	E	E
Number of Empty Travel of MHE				E	(MM)	(MM)	(SM)	E	(MM)	(MM)
Adjacency Score					E	E	E	MM	MM	MM
Speed						E	E	MM	MM	MM
Intermodule Distances							E	MM	SM	MM
Accessibility								E	E	E
Aspect Ratio									E	E
Interferences (Overlapping)										E

Table 204: Pairwise Comparison of Expert 5 with respect to Non-Material Flow

Non-Material Flow	Information Flow (Frequency)	Personnel Flow (Frequency)	Equipment Flow (Frequency)
Information Flow (Frequency)	E	MM	E
Personnel Flow (Frequency)		E	MM
Equipment Flow (Frequency)			E

Table 205: Pairwise Comparison of Expert 5 with respect to Robustness

Robustness	Robustness of Equipment	Building Expansion	Free Space Availability
Robustness of Equipment	E	E	(MM)
Building Expansion		E	E
Free Space Availability			E

Table 206: Pairwise Comparison of Expert 5 with respect to Volume Flexibility

Volume Flexibility	Adaptation to Variations in Production Volume	Adaptation to Variations in Demand Volume	Adaptation to Variations in Material Handling Cost	Adaptation to Variations in Material Flow	Adaptation to Variations in Equipment	Adaptation to Variations in Technology	Adaptation to Variations in Product Mix	Adaptation to Variations in Order Arrival Time	Adaptation to Variations in Processing Requirements	Adaptation to Variations in Due Date Requirements	Adaptation to Variations in Processing Time
Adaptation to Variations in Production Volume	E	(MM)	E	E	(MM)	(MM)	(MM)	MM	MM	MM	(MM)
Adaptation to Variations in Demand Volume		E	MM	MM	E	E	E	SM	SM	SM	MM
Adaptation to Variations in Material Handling Cost			E	E	(MM)	(MM)	(MM)	MM	MM	MM	(MM)
Adaptation to Variations in Material Flow				E	(MM)	(MM)	(MM)	MM	MM	MM	E
Adaptation to Variations in Equipment					E	E	E	SM	MM	MM	E
Adaptation to Variations in Technology						E	E	SM	MM	MM	MM
Adaptation to Variations in Product Mix							E	SM	MM	MM	E
Adaptation to Variations in Order Arrival Time								E	E	E	(MM)
Adaptation to Variations in Processing Requirements									E	E	(MM)
Adaptation to Variations in Due Date Requirements										E	E
Adaptation to Variations in Processing Time											E

Table 207: Pairwise Comparison of Expert 5 with respect to Routing Flexibility

Routing Flexibility	Average Number of Alternate Routes	Accessibility of Alternate Routes
Average Number of Alternate Routes	E	E
Accessibility of Alternate Routes		E

Table 208: Pairwise Comparison of Expert 5 with respect to Topography and Topology

Topography and Topology	Natural Site Conditions and Construction	Truck Access and Circulation Pattern	Connection with External MHE
Natural Site Conditions and Construction	E	E	E
Truck Access and Circulation Pattern		E	(MM)
Connection with External MHE			E

Table 209: Pairwise Comparison of Expert 5 with respect to Community Environment

Community Environment	Impact of Traffic Congestion and Noise	Waste Management and Pollution Control	Appearance of External or Viewable Features
Impact of Traffic Congestion and Noise	E	E	E
Waste Management and Pollution Control		E	E
Appearance of External or Viewable Features			E

Table 210: Pairwise Comparison of Expert 5 with respect to Human-related Safety

Human-related Safety	Human Building Accidents	Human Vehicle Crossings	Human/Machine/Material/Material Handling Interfaces	Fire / Earthquake / Evacuation
Human Building Accidents	E	MM	E	(MM)
Human Vehicle Crossings		E	(MM)	(SM)
Human/Machine/Material/Material Handling Interfaces			E	(MM)
Fire / Earthquake / Evacuation				E

Table 211: Pairwise Comparison of Expert 5 with respect to Worker-related Comfort

Worker-related Comfort	Lighting	Aesthetics	Ease of Supervision	Noise	Ventilation / Heating	Ergonomics	Handicapped Access	Employee Satisfaction	Hygiene	Humidity	Pressure	Signs and Artifacts
Lighting	E	E	(MM)	E	E	(MM)	E	(MM)	(MM)	E	E	E
Aesthetics		E	(MM)	E	E	(MM)	E	(MM)	(MM)	E	E	E
Ease of Supervision			E	MM	MM	E	MM	E	E	MM	MM	MM
Noise				E	E	(MM)	E	(MM)	E	E	E	E
Ventilation / Heating					E	(MM)	E	(MM)	E	E	E	E
Ergonomics						E	MM	E	MM	MM	MM	E
Handicapped Access							E	(MM)	(MM)	E	E	E
Employee Satisfaction								E	E	MM	MM	MM
Hygiene									E	MM	MM	MM
Humidity										E	E	E
Pressure											E	E
Signs and Artifacts												E

Table 212: Pairwise Comparison of Expert 5 with respect to Property-related Security

Property-related Security	Theft from outside the Building	Theft from within the Building	Special Caution for Dangerous Areas
Theft from outside the Building	E	MM	(MM)
Theft from within the Building		E	(SM)
Special Caution for Dangerous Areas			E

Table 213: Pairwise Comparison of Expert 5 with respect to Maintenance

Maintenance	Compatibility of Building Construction and MHE	Space for Maintenance Work	Appropriate Location of Maintenance Activities	Complexity of MHE
Compatibility of Building Construction and MHE	E	E	(MM)	MM
Space for Maintenance Work		E	(MM)	MM
Appropriate Location of Maintenance Activities			E	SM
Complexity of MHE				E

Table 214: Pairwise Comparison of Expert 5 with respect to Sustainability

Sustainability	Number of Reused / Recycled Materials	Environmental Sustainability Index	Environmental Performance Index
Number of Reused / Recycled Materials	E	E	(MM)
Environmental Sustainability Index		E	E
Environmental Performance Index			E

Table 215: Pairwise Comparison of Expert 5 with respect to Time in Production

Time in Production	Production Time	Setup Time	Throughput Time	Overall Processing Time	Cycle Time	Idle Time
Production Time	E	SM	E	(MM)	MM	SM
Setup Time		E	(SM)	(SM)	(MM)	E
Throughput Time			E	(MM)	(MM)	(SM)
Overall Processing Time				E	SM	SM
Cycle Time					E	E
Idle Time						E

Table 216: Pairwise Comparison of Expert 5 with respect to Time in non-Production

Time in Non-Production	Storage Time	Retrieval Time	Loading Time	Unloading Time	Stoppages	Transportation Time
Storage Time	E	E	(MM)	E	MM	(MM)
Retrieval Time		E	(MM)	E	MM	(MM)
Loading Time			E	MM	SM	E
Unloading Time				E	MM	E
Stoppages					E	(MM)
Transportation Time						E

Table 217: Pairwise Comparison of Expert 5 with respect to Production Characteristics

Production Characteristics	Production Volume	Production / Machine Capacity	Total Quality Management (Kaizen)	Quality of the Product	Raw Material Inventory	WIP Inventory	Finished Goods Inventory
Production Volume	E	E	MM	E	MM	MM	SM
Production / Machine Capacity		E	E	E	MM	MM	SM
Total Quality Management (Kaizen)			E	(MM)	E	E	MM
Quality of the Product				E	MM	MM	SM
Raw Material Inventory					E	E	MM
WIP Inventory						E	MM
Finished Goods Inventory							E

Table 218: Pairwise Comparison of Expert 5 with respect to Other Characteristics

Other Characteristics	Average Machine Utilization	Size	Shape of Departments	Shape of Machines	Number of Departments	Number of Machines	Average Availability of Facilities	Manpower Requirements (Skills, Qualifications)
Average Machine Utilization	E	MM	MM	MM	MM	MM	MM	MM
Size		E	(MM)	(MM)	(MM)	(MM)	(MM)	(MM)
Shape of Departments			E	E	E	E	E	E
Shape of Machines				E	E	E	E	E
Number of Departments					E	E	E	E
Number of Machines						E	E	E
Average Availability of Facilities							E	E
Manpower Requirements (Skills, Qualifications)								E

REFERENCES

Abedzadeh, M., Mazinani, M., Moradinasab, N., and Roghanian, E. 2013. *Parallel variable neighborhood search for solving fuzzy multi-objective dynamic facility layout problem*. International Journal of Advanced Manufacturing Technology, Vol. 65: 197-211.

Acar, Y., Kadipasaoglu, S.N., and Day, J.M. 2009. *Incorporating uncertainty in optimal decision making: Integrating mixed integer programming and simulation to solve combinatorial problems.* Computers and Industrial Engineering, Vol. 56: 106-112.

Abdinnour-Helm, S., and Hadley, S.W. 2000. *Tabu search based heuristics for multi-floor facility layout*. International Journal of Production Research, Vol. 38(2): 365-383.

Adrian, A.M., Utamima, A., and Wang, K.J. 2015. *A Comparative Study of GA, PSO and ACO for Solving Construction Site Layout Optimization*. KSCE Journal of Civil Engineering, Vol. 19(3): 520-527.

Agarwal, A., Shankar, R., and Tiwari, M., 2007. *Modeling agility of supply chain*. Industrial Marketing Management, Vol. 36(4): 443–457.

Ahmad, A.R., Basir, O.A., Imam, M.H., and Hassanein, K. 2006. *An efficient, effective, and robust decoding heuristic for metaheuristics-based layout optimization*. International Journal of Production Research, Vol. 44(8): 1545-1567.

Aiello, G., and Enea, M. 2001. *Fuzzy approach to the robust facility layout in uncertain production environments*. International Journal of Production Research, Vol. 39(18): 4089-4101.

Aiello, G., Enea, M., and Galante, G. 2002. *An integrated approach to the facilities and material handling system design*. International Journal of Production Research, Vol. 40(15): 4007-4017.

Aiello, G., Scalia, G.L., and Enea, M. 2012. *A multi objective genetic algorithm for the facility layout problem based upon slicing structure encoding*. Expert Systems with Applications, Vol. 39: 10352-10358.

Aiello, G., Scalia, G.L., and Enea, M. 2013. *A non-dominated ranking Multi Objective Genetic Algorithm and electre method for unequal area facility layout problems*. Expert Systems with Applications, Vol. 40: 4812-4819.

Alagoz, O., Norman, B.A., and Smith A.E. 2008. *Determining aisle structures for facility designs using a hierarchy of algorithms*. IIE Transactions, Vol. 40(11): 1019-1031.

Al-Araidah, O., Krishnamurthy, A., and Malmborg, C.J. 2007. *A comparative study of single-phase and two-phase approaches for the layout problem with material handling costs*. International Journal of Production Research, Vol. 45(4): 951-970.

Al-Hakim, L. 2000. *On solving facility layout problems using genetic algorithms*. International Journal of Production Research, Vol. 38(11): 2573-2582.

Al-Hawari, T., Mumani, A., and Momani, A. 2014. *Application of the Analytic Network Process to facility layout selection*. Journal of Manufacturing Systems, Vol. 33: 488-497.

Allahyari, M.Z., and Azab, A. 2015. *A Novel Bi-level Continuous Formulation for the Cellular Manufacturing System Facility Layout Problem*. Procedia CIRP, Vol. 33: 87-92.

Altuntas, S., and Selim, H. 2012. *Facility layout using weighted association rule-based data mining algorithms: Evaluation with simulation*. Expert Systems with Applications, Vol. 39: 3-13.

Altuntas, S., Selim, H., and Dereli, T. 2014. *A fuzzy DEMATEL-based solution approach for facility layout problem: a case study*. International Journal of Advanced Manufacturing Technology, Vol. 73: 749-771.

Alvarenga, A.G., Negreiros-Gomes, F.J., and Mestria, M. 2000. *Metaheuristic methods for a class of the facility layout problem*. Journal of Intelligent Manufacturing, Vol. 11: 421-430.

Amaral, A.R.S. 2006. *On the exact solution of a facility layout problem*. European Journal of Operational Research, Vol. 173: 508-518.

Amaral, A.R.S. 2009. *A new lower bound for the single row facility layout problem*. Discrete Applied Mathematics, Vol. 157: 183-190.

Amaral, A.R.S. 2012. *The corridor allocation problem*. Computers and Operations Research, Vol. 39: 3325-3330.

Amaral, A.R.S. 2013. *Optimal solutions for the double row layout problem*. Optimization Letters, Vol. 7: 407-413.

Amaral, A.R.S. 2013b. *A parallel ordering problem in facilities layout*. Computers and Operations Research, Vol. 40: 2930-2939.

Ariafar, S., and Ismail, N. 2009. *An improved algorithm for layout design in cellular manufacturing systems*. Journal of Manufacturing Systems, Vol. 28: 132-139.

Ashayeri, J., Heuts, R., and Tammel B. 2005. *A modified simple heuristic for the p-median problem, with facilities design applications*. Robotics and Computer-Integrated Manufacturing, Vol. 21: 451-464.

Azadeh, A., Moghaddam, M., Asadzadeh, S.M., and Negahban, A. 2011. *An integrated fuzzy simulation-fuzzy data envelopment analysis algorithm for job-shop layout optimization: The case of injection process with ambiguous data*. European Journal of Operational Research, Vol. 214: 768-779.

Azadeh, A., Haghighi, S.M., Asadzadeh, S.M., and Saedi, H. 2013. *A new approach for layout optimization in maintenance workshops with safety factors: The case of a gas transmission unit*. Journal of Loss Prevention in the Process Industries, Vol. 26: 1457-1465.

Azadeh, A., Haghighi, S.M., Asadzadeh, S.M. 2014. *A novel algorithm for layout optimization of injection process withrandom demands and sequence dependent setup times*. Journal of Manufacturing Systems, Vol. 33: 287-302.

Azadeh, A., Nazari, T., and Charkhand, H. 2015. *Optimization of facility layout design problem with safety and environmental factors by stochastic DEA and simulation approach*. International Journal of Production Research, Vol. 53(11): 3370-3389.

Azadivar, F., and Wang, J. 2000. *Facility layout optimization using simulation and genetic algorithms*. International Journal of Production Research, Vol. 38(17): 4369-4383.

Babbage, C. 1832. *On the Economy of Machinery and Manufactures*. R. Clay, Printer, London.

Balakrishnan, J., Cheng, C.H., and Wong, K.F. 2003. *FACOPT: a user friendly FACility layout OPTimization system*. Computers and Operations Research, Vol. 30: 1625-1641.

Barral, D., Perrin, J.P., Dombre, E., and Liégeois, A. 2001. *Simulated Annealing Combined with a Constructive Algorithm for Optimising Assembly Workcell Layout*. International Journal of Advanced Manufacturing Technology, Vol. 17: 593–602.

Baykasoglu, A., Dereli, T., and Sabuncu, I. 2006. *An ant colony algorithm for solving budget constrained and unconstrained dynamic facility layout problems*. Omega, Vol. 34: 385-396.

Bazargan-lari, M., and Kaebernick, H. 1997. *An approach to the machine layout problem in a cellular manufacturing environment*. Production Planning & Control, Vol. 8(1): 41-55.

Benjaafar, S., and Sheikhzadeh, M. 2000. *Design of flexible plant layouts*. IIE Transactions, Vol. 32(4): 309-322.

Bock, S., and Hoberg, K. 2007. *Detailed layout planning for irregularly-shaped machines with transportation path design*. European Journal of Operational Research, Vol. 177: 693-718.

Bozer, Y.A., and Wang, C.T. 2012. *A graph-pair representation and MIP-model-based heuristic for the unequal-area facility layout problem*. European Journal of Operational Research, Vol. 218: 382-391.

Bozorgi, N., Abedzadeh, M., and Zeinali M. 2015. *Tabu search heuristic for efficiency of dynamic facility layout problem*. International Journal of Advanced Manufacturing Technology, Vol. 77: 689-703.

Caccetta, L., and Kusumah, Y.S. 2001. *Computational Aspects of the Facility Layout Problem*. Nonlinear Analysis, Vol. 47: 5599-5610.

Caputo, A.C., Pelagagge, P.M., Palumbo, M., and Salini, P. 2015. *Safety-based process plant layout using genetic algorithm.* Journal of Loss Prevention in the Process Industries, Vol. 34: 139-150.

Castillo, I., and Peters, B.A. 2002. *Unit load and material-handling considerations in facility layout design*. International Journal of Production Research, Vol. 40(13): 2955-2989.

Castillo, I., and Peters, B.A. 2003. *An extended distance-based facility layout problem*. International Journal of Production Research, Vol. 41(11): 2451-2479.

Castillo, I., and Peters, B.A. 2004. *Integrating design and production planning considerations in multi-bay manufacturing facility layout*. European Journal of Operational Research, Vol. 157: 671-687.

Castillo, I., and Sim, T. 2004. *A Spring-Embedding Approach for the Facility Layout Problem*. Journal of the Operational Research Society, Vol. 55: 73-81.

Castillo, I., and Westerlund, T. 2005. *An ε-accurate model for optimal unequal-area block layout design*. Computers and Operations Research, Vol. 32: 429-447.

Chae, J., and Peters, B.A. 2006. *A simulated annealing algorithm based on a closed loop layout for facility layout design in flexible manufacturing systems*. International Journal of Production Research, Vol. 44(13): 2561-2572.

Chae, J., and Peters, B.A. 2006b. *Layout Design of Multi-Bay Facilities with Limited Bay Flexibility*. Journal of Manufacturing Systems, Vol. 25(1): 1-11.

Chang, P.T., Lee, J.H., Hung, K.C., Tasi, J.T., and Perng, C. 2009. *Applying fuzzy weighted average approach to evaluate office layouts with Feng-Shui consideration*. Mathematical and Computer Modelling, Vol. 50: 1514-1537.

Chang, M.S., and Ku, T.C. 2013. *A Slicing Tree Representation and QCP-Model-Based Heuristic Algorithm for the Unequal-Area Block Facility Layout Problem*. Mathematical Problems in Engineering, Vol. 2013: 1-19.

Chen S.J., and Hwang C.L. 1992. *Fuzzy multiple attribute decision making*. Lecture Notes in Economics and Mathematical Systems Vol. 375.

Chen, C.W., and Sha, D.Y. 2005. *Heuristic approach for solving the multi-objective facility layout problem*. International Journal of Production Research, Vol. 43(21): 4493-4507.

Chen, G.Y.H. 2013. *A new data structure of solution representation in hybrid ant colony optimization for large dynamic facility layout problems*. International Journal of Production Economics, Vol. 142: 362-371.

Cheng, M.Y., Lien, L.C. 2012. *A hybrid AI-based particle bee algorithm for facility layout optimization*. Engineering with Computers, Vol. 28: 57-69.

Chiang, W.C. 2001. *Visual facility layout design system*. International Journal of Production Research, Vol. 39(9): 1811-1836.

Chiang, W.C., and Chiang, C. 1998. *Intelligent local search strategies for solving facility layout problems with the quadratic assignment problem formulation*. European Journal of Operational Research, Vol. 106: 457-488.

Chiang, W.C., Kouvelis, P., and Urban, T.L. 2006. *Single- and multi-objective facility layout with workflow interference considerations*. European Journal of Operational Research, Vol. 174: 1414-1426.

Chittratanawat, S., and Noble, J.S. 1999. *An integrated approach for facility layout, P/D location and material handling system design*. International Journal of Production Research, Vol. 37(3): 683-706.

Chung, S.H., Lee, A.H., and Pearn, W.L. 2005. *Product mix optimization for semiconductor manufacturing based on AHP and ANP analysis*. International Journal of Advanced Manufacturing Technology, Vol. 25: 1144–1156.

Chung, J., and Tanchoco, J.M.A. 2010. *Layout design with hexagonal floor plans and material flow patterns*. International Journal of Production Research, Vol. 48(12): 3407-3428.

Chung, J., and Tanchoco, J.M.A. 2010b. *The double row layout problem*. International Journal of Production Research, Vol. 48(3): 709-727.

Chwif, L., Barretto, M.R.P., and Moscato, L.A. 1998. *A solution to the facility layout problem using simulated annealing*. Computers in Industry, Vol. 36: 125-132.

Datta, D., Amaral, A.R.S., and Figueira, J.R. 2011. *Single row facility layout problem using a permutation-based genetic algorithm*. European Journal of Operational Research, Vol. 213: 388-394.

Deb, S.K., and Bhattacharyya, B. 2003. *Facilities layout planning based on Fuzzy multiple criteria decision-making methodology*. International Journal of Production Research, Vol. 41(18): 4487-4504.

Deb, S.K., and Bhattacharyya, B. 2005. *Solution of facility layout problems with pickup/drop-off locations using random search techniques*. International Journal of Production Research, Vol. 43(22): 4787-4812.

Deb, S.K., and Bhattacharyya, B. 2005b. *Fuzzy decision support system for manufacturing facilities layout planning*. Decision Support Systems, Vol. 40: 305-314.

Delmaire, H., Langevin, A., and Riopel, D. 1997. *Skeleton-based facility layout design using genetic algorithms*. Annals of Operations Research, Vol. 69: 85-104.

Diego-Mas, J.A., Santamarina-Siurana, M.C., Cloquell-Ballester, V.A., and Alcaide-Marzal, J. 2008. *Slicing tree's geometric potential: an indicator for layout problems based on slicing tree structure*. International Journal of Production Research, Vol. 46(4): 1071-1087.

Diego-Mas, J.A., Santamarina-Siurana, M.C., Alcaide-Marzal, J., and Cloquell-Ballester, V.A. 2009. *Solving facility layout problems with strict geometric constraints using a two-phase genetic algorithm*. International Journal of Production Research, Vol. 47(6): 1679-1693.

Djellab, H., and Gourgand, M. 2001. *A new heuristic procedure for the single-row facility layout problem*. International Journal of Computer Integrated Manufacturing, Vol. 14(3): 270-280.

Dokeroglu, T. 2015. *Hybrid teaching–learning-based optimization algorithms for the Quadratic Assignment Problem*. Computers and Industrial Engineering, Vol. 85: 86-101.

Dombrowski, U., and Ernst, S. 2013. *Scenario-based simulation approach for layout planning*. Procedia CIRP, Vol. 12: 354-359.

Dong, M., Wu, C., and Hou, F. 2009. *Shortest path based simulated annealing algorithm for dynamic facility layout problem under dynamic business environment*. Expert Systems with Applications, Vol. 36: 11221-11232.

Dorigo, M., and Stützle, T. 2004. *Ant colony optimization*. The MIT Press, Cambridge

Drezner, Z. 2010. *On the unboundedness of facility layout problems*. Mathematical Methods of Operations Research, Vol. 72: 205-216.

Drira, A., Pierreval, H., and Hajri-Gabouj, S. 2013. *Design of a robust layout with information uncertainty increasing over time: A fuzzy evolutionary approach*. Engineering Applications of Artificial Intelligence, Vol. 26: 1052-1060.

Dunker, T., Radons, G., and Westkämper, E. 2003. *A coevolutionary algorithm for a facility layout problem*. International Journal of Production Research, Vol. 41(15): 3479-3500.

Dunker, T., Radons, G., and Westkämper, E. 2005. *Combining evolutionary computation and dynamic programming for solving a dynamic facility layout problem*. European Journal of Operational Research, Vol. 165: 55-69.

Duran, O, and Aguilo, J. 2008. *Computer-aided machine-tool selection based on a Fuzzy-AHP approach*. Expert Systems with Applications, Vol. 34: 1787-1794.

Dweiri, F. 1999. *Fuzzy development of crisp activity relationship charts for facilities layout*. Computers and Industrial Engineering, Vol. 36: 1-16.

Eklund, N.H.W., Embrechts, M.J., and Goetschalckx, M. 2006. *Efficient Chromosome Encoding and Problem-Specific Mutation Methods for the Flexible Bay Facility Layout Problem*. IEEE Transactions on Systems, Man, and Cybernetics-Part C: Applications and Reviews, Vol. 36(4): 495-502.

El-Baz, M.A. 2004. *A genetic algorithm for facility layout problems of different manufacturing environments*. Computers and Industrial Engineering, Vol. 47: 233-246.

Emami, S., and Nookabadi, A.S. 2013. *Managing a new multi-objective model for the dynamic facility layout problem*. International Journal of Advanced Manufacturing Technology, Vol. 68: 2215-2228.

Enea, M., Galante, G., and Panascia, E. 2005. *The facility layout problem approached using a fuzzy model and a genetic search*. Journal of Intelligent Manufacturing, Vol. 16: 303-316.

Ertay, T., Ruan, D., and Tuzkaya, U.R. 2006. *Integrating data envelopment analysis and analytic hierarchy for the facility layout design in manufacturing systems*. Information Sciences, Vol. 176: 237-262.

Evans, G.W., Wilhelm, M.R., and Karwowski, W. 1987. *A layout design heuristic employing the theory of fuzzy sets*. International Journal of Production Research, Vol. 25(10): 1431-1450.

Fan, Z., and Liu, Y. 2010. *A method for group decision-making based on multi-granularity uncertain linguistic information*. Expert Systems with Applications, Vol. 37(5): 4000–4008.

Farris, D., and Sage, A. 1975. *On the use of interpretive structural modeling for worth assessment*. Computers and Electrical Engineering, Vol. 2(2): 149–174.

Fayol, H. 1984. *General and Industrial Management*. Institute of Electrical and Electronics Engineers, New York.

Filho, E.V.G., and Tiberti, A.J. 2006. *A group genetic algorithm for the machine cell formation problem*. International Journal of Production Economics, Vol. 102: 1-21.

Foroughi, A. 2011. *A new mixed integer linear model for selecting the best decision making units in data envelopment analysis*. Computers and Industrial Engineering, Vol. 60: 550-554.

Foulds, L.R., and Partovi, F.Y. 1998. *Integrating the analytic hierarchy process and graph theory to model facilities layout*. Annals of Operations Research, Vol. 82: 435-451.

Francis R.L., McGinnis L.F., and White J.A. 2009. *Facility layout and location, an analytical approach (2nd edition)*, Prentice-Hall, New Delhi.

Gabus, A., and Fontela, E. 1972. *World problems, an invitation to further thought within the framework of DEMATEL*. Switzerland, Geneva: Battelle Geneva Research Centre.

Gabus, A., and Fontela, E. 1973. *Perceptions of the world problematique: Communication procedure, communicating with those bearing collective responsibility (DEMATEL report no. 1).* Switzerland Geneva: Battelle Geneva Research Centre

Gamberi, M., Manzini, R., and Regattieri, A. 2009. *An new approach for the automatic analysis and control of material handling systems: integrated layout flow analysis (ILFA).* International Journal of Advanced Manufacturing Technology, Vol. 41: 156-167.

Gantz, S.P., and Pettit, R.B. 1953. *Plant layout efficiency*. Modern Materials Handling, Vol. 9(1): 65-67.

Garcia-Hernandez, L., Arauzo-Azofra, A., Salas-Morera, L., Pierreval, H., and Corchado, E. 2013. *Recycling Plants Layout Design by Means of an Interactive Genetic Algorithm*. Intelligent Automation and Soft Computing, Vol. 19(3): 457-468.

Garcia-Hernandez, L., Pierreval, H., Salas-Morera, L., and Arauzo-Azofra, A. 2013b. *Handling qualitative aspects in Unequal Area Facility Layout Problem: An Interactive Genetic Algorithm*. Applied Soft Computing, Vol. 13: 1718-1727.

Garcia-Hernandez, L., Arauzo-Azofra, A., Salas-Morera, L., Pierreval, H., and Corchado, E. 2015. *Facility layout design using a multi-objective interactive genetic algorithm to support the DM*. Expert Systems, Vol. 32(1): 94-107.

Garcia-Hernandez, L., Palomo-Romero, J.M., Salas-Morera, L., Arauzo-Azofra, A., and Pierreval, H. 2015b. *A novel hybrid evolutionary approach for capturing decision maker knowledge into the unequal area facility layout problem*. Expert Systems with Applications, Vol. 42: 4697-4708.

Gau, K.Y., Meller, R.D. 1999. *An iterative facility layout algorithm*. International Journal of Production Research, Vol. 37(16): 3739-3758.

Georgiadis, M.C., Schilling, G., Rotstein, G.E., and Macchietto, S. 1999. *A general mathematical programming approach for process plant layout*. Computers and Chemical Engineering, Vol. 23: 823-840.

Gonçalves, J.F., and Resende, M.G.C. 2015. *A biased random-key genetic algorithm for the unequal area facility layout problem*. European Journal of Operational Research, Vol. 246: 86-107.

Gonzalez-Cruz, M.C., Martinez, E.G.S. 2011. *An entropy-based algorithm to solve the facility layout design problem*. Robotics and Computer-Integrated Manufacturing, Vol. 27: 88-100.

Gress, E.S.H., Mora-Vargas, J., Herrera del Canto, L.E., and Díaz-Santillán, E. 2011. *A genetic algorithm for optimal unequal-area block layout design*. International Journal of Production Research, Vol. 49(8): 2183-2195.

Guan, J., and Lin, G. 2016. *Hybridizing variable neighborhood search with ant colony optimization for solving the single row facility layout problem*. European Journal of Operational Research, Vol. 248: 899-909.

Hadi-Vencheh, A., Mohamadghasemi, A. 2013. *An integrated AHP–NLP methodology for facility layout design*. Journal of Manufacturing Systems, Vol. 32: 40-45.

Hadi-Vencheh, A., and Mohamadghasemi, A. 2015. *A new hybrid fuzzy multi-criteria decision making model for solving the material handling equipment selection problem*. International Journal of Computer Integrated Manufacturing, Vol. 28(5): 534-550.

Hamamoto, 1999. *Development and validation of genetic algorithm based facility layout a case study in the pharmaceutical industry*. International Journal of Production Research, Vol. 37(4): 749-768.

Haq, A.N., Karthikeyan, T., and Dinesh, M. 2003. *Scheduling decisions in FMS using a heuristic approach*. International Journal of Advanced Manufacturing Technology, Vol. 22: 374-379.

Hathhorn, J., Sisikoglu, E., and Sir, M.Y. 2013. *A multi-objective mixed-integer programming model for a multi-floor facility layout*. International Journal of Production Research, Vol. 51(14): 4223-4239.

Hauser, K., and Chung, C.H. 2006. *Genetic algorithms for layout optimization in crossdocking operations of a manufacturing plant*. Journal of Production Research, Vol. 44(21): 4663-4680.

Heizer, J., and Render, B. 2014. *Operations Management: Sustainability and Supply Chain Management*. 11th edition, Pearson Eduation, Inc.

Hervani, A.A., Helms, M.M., and Sarkis, J. 2005. *Performance measurement for green supply chain management*. Benchmarking: An International Journal, Vol. 12(4): 330-353.

Hess, P., and Siciliano, J. 1996. *Management: Responsibility for performance*. New York: McGraw-Hill.

Hicks, C. 2006. *A Genetic Algorithm tool for optimising cellular or functional layouts in the capital goods industry*. International Journal of Production Economics, Vol. 104: 598-614.

Hosseini, S., Khaled, A.A., and Vadlamani, S. 2014. *Hybrid imperialist competitive algorithm, variable neighborhood search, and simulated annealing for dynamic facility layout problem*. Neural Computing and Applications, Vol. 25: 1871-1885.

Hosseini-Nasab, H., and Emami, L. 2013. *A hybrid particle swarm optimization for dynamic facility layout problem*. International Journal of Production Research, Vol. 51(14): 4325-4335.

Hosseini-Nasab, H. 2014. *A hybrid fuzzy-GA algorithm for the integrated machine allocation problem with fuzzy demands*. Applied Soft Computing, Vol. 23: 417-431.

Hsieh, C.H., Cho, C., Yang, T., and Chang, T.J. 2012. *Simulation study for a proposed segmented automated material handling system design for 300-mm semiconductor fabs*. Simulation Modelling Practice and Theory, Vol. 29: 18-31.

Hu, G.H., Chen, Y.P., Zhou, Z.D., and Fang, H.C. 2007. *A genetic algorithm for the inter-cell layout and material handling system design*. International Journal of Advanced Manufacturing Technology, Vol. 34: 1153-1163.

Huang, S., Batta, R., and Nagi, R. 2003. *Variable capacity sizing and selection of connections in a facility layout*. IIE Transactions, Vol. 35(1): 49-59.

Hungerländer, P., and Anjos, M.F. 2015. *A semidefinite optimization-based approach for global optimization of multi-row facility layout*. European Journal of Operational Research, Vol. 245: 46-61.

Hwang, H.S. 2004. *Heuristic transporter routing model for manufacturing facility design*. Computers and Industrial Engineering, Vol. 46: 243-251.

Ioannou, G. 2006. *Time-phased creation of hybrid manufacturing systems*. International Journal of Production Economics, Vol. 102: 183-198.

Ioannou, G. 2007. *An integrated model and a decomposition-based approach for concurrent layout and material handling system design*. Computers and Industrial Engineering, Vol. 52: 459-485.

Irani, S.A., and Huang, H. 2000. *Custom Design of Facility Layouts for Multiproduct Facilities Using Layout Modules*. IEEE Transactions on Robotics and Automation, Vol. 16(3): 259-267.

Islier, A.A. 1998. *A genetic algorithm approach for multiple criteria facility layout design*. International Journal of Production Research, Vol. 36(6): 1549-1569.

Izui, K., Murakumo, Y., Suemitsu, I., Nishiwaki, S., Noda, A., and Nagatani, T. 2013. *Multiobjective layout optimization of robotic cellular manufacturing systems*. Computers and Industrial Engineering, Vol. 64: 537-544.

Jabal-Ameli, M.S., and Moshref-Javadi, M. 2014. *Concurrent cell formation and layout design using scatter search*. International Journal of Advanced Manufacturing Technology, Vol. 71: 1-22.

Jankovits, I., Luo, C., Anjos, M.F., and Vannelli, A. 2011. *A convex optimisation framework for the unequal-areas facility layout problem*. European Journal of Operational Research, Vol. 214: 199-215.

Javadi, B., Jolai, F., Slomp, J., Rabbani, M., and Tavakkoli-Moghaddam, R. 2013. *An integrated approach for the cell formation and layout design in cellular manufacturing systems*. International Journal of Production Research, Vol. 51(20): 6017-6044.

Jharkharia, S., and Shankar, R. 2005. *IT-enablement of supply chains: Understanding the barriers*. Journal of Enterprise Information Management, Vol. 18(1): 11–27.

Jia, Q., and Seo, Y. 2013. *Solving resource-constrained project scheduling problems: Conceptual validation of FLP formulation and efficient permutation-based ABC computation*. Computers and Operations Research, Vol. 40: 2037-2050.

Jiang, S., Nee, A.Y.C. 2013. *A novel facility layout planning and optimization methodology*. CIRP Annals - Manufacturing Technology, Vol. 62: 483-486.

Jiang, S., Ong, S.K., and Nee, A.Y.C. 2014. *An AR-based hybrid approach for facility layout planning and evaluation for existing shop floors*. International Journal of Advanced Manufacturing Technology, Vol. 72: 457-473.

Jolai, F., Tavakkoli-Moghaddam, R., and Taghipour, M. 2012. *A multi-objective particle swarm optimization algorithm for unequal sized dynamic facility layout problem with pickup/drop-off locations*. International Journal of Production Research, Vol. 50(15): 4279-4293.

Kalita, Z., and Datta, D. 2014. *Solving the bi-objective corridor allocation problem using a permutation-based genetic algorithm*. Computers and Operations Research, Vol. 52: 123-134.

Kaveh, M., Dalfard, M.V., and Amiri, S. 2014. *A new intelligent algorithm for dynamic facility layout problem in state of fuzzy constraints*. Neural Computing and Applications, Vol. 24: 1179-1190.

Keshavarzmanesh, S., Wang, L., and Feng, H.Y. 2010. *A hybrid approach for dynamic routing planning in an automated assembly shop*. Robotics and Computer-Integrated Manufacturing, Vol. 26: 768-777.

Khaksar-Haghani, F., Kia, R., Mahdavi, I., and Kazemi, M. 2013. *A genetic algorithm for solving a multi-floor layout design model of a cellular manufacturing system with alternative process routings and flexible configuration*. International Journal of Advanced Manufacturing Technology, Vol. 66: 845-865.

Khatwani, G., Singh, S. P., Trivedi, A., and Chauhan, A. 2015. *Fuzzy-TISM: A Fuzzy Extension of TISM for Group Decision Making*. Global Journal of Flexible Systems Management, Vol. 16(1): 97–112.

Kheirkhah, A., Navidi, H., and Bidgoli, M.M. 2015. *Dynamic Facility Layout Problem: A New Bilevel Formulation and Some Metaheuristic Solution Methods*. IEEE Transactions on Engineering Management, Vol. 62(3): 396-410.

Khilwani, N., Shankar, R., and Tiwari, M.K. 2008. *Facility layout problem: an approach based on a group decision-making system and psychoclonal algorithm*. International Journal of Production Research, Vol. 46(4): 895-927.

Kia, R., Khaksar-Haghani, F., Javadian, N., and Tavakkoli-Moghaddam, R. 2014. *Solving a multi-floor layout design model of a dynamic cellular manufacturing system by an efficient genetic algorithm*. Journal of Manufacturing Systems, Vol. 33: 218-232.

Kim, C.B., Foote, B.L., and Pulat, P.S. 1995. *Cut-Tree Construction for Facility Layout*. Computers and Industrial Engineering, Vol. 28(4): 721-730.

Kim, J.G., and Goetschalckx, M. 2005. *An integrated approach for the concurrent determination of the block layout and the input and output point locations based on the contour distance*. International Journal of Production Research, Vol. 43(10), 2027-2047.

Kim, J.Y., and Kim, Y.D. 1995. *Graph Theoretic Heuristics for Unequal-sized Facility Layout Problems*. Omega, Vol. 23(4): 391-401.

Kim, J.G., and Kim, Y.D. 1998. *A space partitioning method for facility layout problems with shape constraints*. IIE Transactions, Vol. 30(10): 947-957.

Kim, J.G., and Kim, Y.D. 2000. *Layout planning for facilities with fixed shapes and input and output points*. International Journal of Production Research, Vol. 38(18): 4635-4653.

Kim, J.G., and Kim Y.D. 2003. *A Linear Programming-Based Algorithm for Floorplanning in VLSI Design*. IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, Vol. 22(5): 584-592.

Kim, S., Chung, H., and Kim, M. 2014. *Optimization of P.E. area division and arrangement based on product mix*. Journal of Marine Science and Technology, Vol. 19: 35—359.

Kochhar, J.S., Foster, B.T., Heragu, S.S. 1998. *Hope: Genetic Algorithm for the Unequal Area Facility Layout Problem*. Computers and Operations Research, Vol. 25(7/8): 583-594.

Kochhar, J.S., and Heragu, S.S. 1999. *Facility layout design in a changing environment*. International Journal of Production Research, Vol. 37(11): 2429-2446.

Komarudin, and Wong, K.Y. 2010. *Applying Ant System for solving Unequal Area Facility Layout Problems*. European Journal of Operational Research, Vol. 202: 730-746.

Konak, A., Kulturel-Konak, S., Norman, B.A., and Smith, A.E. 2006. *A new mixed integer programming formulation for facility layout design using flexible bays*. Operations Research Letters, Vol. 34: 660-672.

Konz, S. 1985. *Facility Design*. Wiley, New York.

Koopmans, T.J., and Beckmann, M. 1957. *Assignment Problems and the Location of Economics Activities*. Econometrica, Vol. 25(1): 53-76.

Kosucuoglu, D., and Bilge, U. 2012. *Material handling considerations in the FMS loading problem with full routing flexibility*. International Journal of Production Research, Vol. 50(22): 6530-6552.

Kothari, R., and Ghosh, D. 2013. *Insertion based Lin–Kernighan heuristic for single row facility layout*. Computers and Operations Research, Vol. 40: 129-136.

Kothari, R., and Ghosh, D. 2013b. *Tabu search for the single row facility layout problem using exhaustive 2-opt and insertion neighborhoods*. European Journal of Operational Research, Vol. 224: 93-100.

Kothari, R., and Ghosh, D. 2014. *A scatter search algorithm for the single row facility layout problem*. Journal of Heuristics, Vol. 20: 125–142.

Kothari, R., and Ghosh, D. 2014b. *An efficient genetic algorithm for single row facility layout*. Optimization Letters, Vol. 8: 679-690.

Krishnan, K.K., Mirzaei, S., Venkatasamy, V., and Pillai, V.M. 2012. *A comprehensive approach to facility layout design and cell formation*. International Journal of Advanced Manufacturing Technology, Vol. 59: 737-753.

Ku, M.Y., Hu, M.H., and Wang, M.J. 2011. *Simulated annealing based parallel genetic algorithm for facility layout problem*. International Journal of Production Research, Vol. 49(6): 1801-1812.

Kulturel-Konak, S., Smith, A.E., and Norman, B.A. 2004. *Layout optimization considering production uncertainty and routing flexibility*. International Journal of Production Research, Vol. 42(21): 4475-4493.

Kulturel-Konak, S., and Konak, A. 2011. *A new relaxed flexible bay structure representation and particle swarm optimization for the unequal area facility layout problem*. Engineering Optimization, Vol. 43(12): 1263-1287.

Kulturel-Konak, S., and Konak, A. 2011b. *Unequal area flexible bay facility layout using ant colony optimisation*. International Journal of Production Research, Vol. 49(7): 1877-1902.

Kulturel-Konak, S. 2012. *A linear programming embedded probabilistic tabu search for the unequal-area facility layout problem with flexible bays*. European Journal of Operational Research, Vol. 223: 614-625.

Kulturel-Konak, S., and Konak A. 2013. *Linear Programming Based Genetic Algorithm for the Unequal Area Facility Layout Problem*. International Journal of Production Research, Vol. 51(14): 4302-4324.

Kulturel-Konak, S., and Konak, A. 2015. *A large-scale hybrid simulated annealing algorithm for cyclic facility layout problems*. Engineering Optimization, Vol. 47(7): 963-978.

Kulturel-Konak, S., Smith, A.E., and Norman, B.A. 2004. *Layout optimization considering production uncertainty and routing flexibility*. International Journal of Production Research, Vol. 42(21): 4475-4493.

Kundu, A., and Dan, P.K. 2010. *The Scope of Genetic Algorithms in Dealing with Facility Layout Problems*. South African Journal of Industrial Engineering, Vol. 21(2): 39-49.

Kuo, Y., Yang, T., and Huang, G.W. 2008. *The use of grey relational analysis in solving multiple attribute decision-making problems*. Computers and Industrial Engineering, Vol. 55: 80-93.

Kusiak A., and Heragu, S. 1987. *The facility layout problem*. European Journal of Operational Research, Vol. 29: 229-251.

Lacksonen, T.A. 1997. *Preprocessing for static and dynamic facility layout problems*. International Journal of Production Research, Vol. 35(4): 1095-1106.

Lee, A.H.I., Kang, H., and Chang, H. 2008. *Evaluating Buyer-Supplier Relationships in HighTech Industry by Analytic Network Process (ANP).* Proceedings of the Service Operations and Logistics, and Informatics, IEEE International Conference on October, Beijing, 2677 – 2682.

Lee, K.Y., Han, S.N., and Roh, M.I. 2003. *An improved genetic algorithm for facility layout problems having inner structure walls and passages*. Computers and Operations Research, Vol. 30: 117-138.

Lee, Y.H., and Lee, M.H. 2002. *A shape-based block layout approach to facility layout problems using hybrid genetic algorithm*. Computers and Industrial Engineering, Vol. 42: 237-248.

Lee, K.Y., Roh, M.I., and Jeong, H.S. 2005. *An improved genetic algorithm for multi-floor facility layout problems having inner structure walls and passages*. Computers and Operations Research, Vol. 32: 879-899.

Lenin, N., Kumar, M.S., Islam, M.N., and Ravindran, D. 2013. *Multi-objective optimization in single-row layout design using a genetic algorithm*. International Journal of Advanced Manufacturing Technology, Vol. 67: 1777-1790.

Leno, I.J., Sankar, S.S., Raj, M.V., and Ponnambalam, S.G. 2013. *An elitist strategy genetic algorithm for integrated layout design*. International Journal of Advanced Manufacturing Technology, Vol. 66: 1573-1589.

Li, R.J. 1999. *Fuzzy method in group decision making*. Computers and Mathematics with Applications, Vol. 38(1): 91–101.

Li, H., and Love, P.E.D. 2000. *Genetic search for solving construction site-level unequal-area facility layout problems*. Automation in Construction, Vol. 9: 217-226.

Li, S.G., and Rong, Y.L. 2009. *The reliable design of one-piece flow production system using fuzzy ant colony optimization*. Computers and Operations Research, Vol. 36: 1656-1663.

Li, L., Li, C., Ma, H., and Tang, Y. 2015. *An Optimization Method for the Remanufacturing Dynamic Facility Layout Problem with Uncertainties*. Discrete Dynamics in Nature and Society, Vol. 2015: 1-11.

Liang, L.Y., and Chao, W.C. 2008. *The strategies of tabu search technique for facility layout optimization*. Automation in Construction, Vol. 17: 657-669.

Lien, L.C., and Cheng, M.Y. 2012. *A hybrid swarm intelligence based particle-bee algorithm for construction site layout optimization*. Expert Systems with Applications, Vol. 39: 9642-9650.

Lin, C.L., and Sharp G.P. 1999. *Quantitative and qualitative indices for the plant layout evaluation problem*. European Journal of Operational Research, Vol. 116: 100-117.

Lin, C.L., and Sharp G.P. 1999b. *Application of the integrated framework for the plant layout evaluation problem*. European Journal of Operational Research, Vol. 116: 118-138.

Lin, C.J., and Wu, W.W. 2008. *A causal analytical method for group decision-making under fuzzy environment*. Expert Systems with Applications, Vol. 34: 205-213.

Lira-Flores, J.D., Vázquez-Román, R., López-Molina, A., and Mannan, M.S. 2014. *A MINLP approach for layout designs based on the domino hazard index*. Journal of Loss Prevention in the Process Industries, Vol. 30: 219-227.

Liu, Q., and Meller, R.D. 2007. *A sequence-pair representation and MIP-modelbased heuristic for the facility layout problem with rectangular departments*. IIE Transactions, Vol. 39(4): 377-394.

Liu, X.B., and Sun, X.M. 2012. *A multi-improved genetic algorithm for facility layout optimisation based on slicing tree*. International Journal of Production Research, Vol. 50(18): 5173-5180.

Logendran, R., and Kriausakul, T. 2006. *A methodology for solving the unequal area facility layout problem using distance and shape-based measures*. International Journal of Production Research, Vol. 44(7), 1243-1272.

Luo, X., Yang, Y., Ge, Z., Wen, X., and Guan, F. 2015. *Maintainability-based facility layout optimum design of ship cabin*. International Journal of Production Research, Vol. 53(3): 677-694.

Mak, K.L., Wong, Y.S., and Chan, F.T.S. 1998. *A genetic algorithm for facility layout problems*. Computer Integrated Manufacturing Systems, Vol. 11(1/2): 113-127.

Maniya, K.D., and Bhatt, M.G. 2011. *An alternative multiple attribute decision making methodology for solving optimal facility layout design selection problems*. Computers and Industrial Engineering, Vol. 61: 542-549.

Matai, R., Singh, S.P., and Mittal, M.L. 2013. *Modified simulated annealing based approach for multi objective facility layout problem*. International Journal of Production Research, Vol. 51(14): 4273-4288.

Matai, R. 2015. *Solving multi objective facility layout problem by modified simulated annealing*. Applied Mathematics and Computation, Vol. 261: 302-311.

Matsuzaki, K., Irohara, T., and Yoshimoto, K. 1999. *Heuristic algorithm to solve the multi-floor layout problem with the consideration of elevator utilization*. Computers and Industrial Engineering, Vol. 36: 487-502.

Mavridou, T.D., and Pardalos, P.M. 1997. *Simulated Annealing and Genetic Algorithms for the Facility Layout Problem: A Survey*. Computational Optimization and Applications, Vol. 7: 111-126.

Mazinani, M., Abedzadeh, M., and Mohebali, N. 2013. *Dynamic facility layout problem based on flexible bay structure and solving by genetic algorithm*. International Journal of Advanced Manufacturing Technology, Vol. 65: 929-943.

Mckendall Jr., A.R., Noble, J.S., and Klein, C.M. 1999. *Facility layout of irregular-shaped departments using a nested approach*. International Journal of Production Research, Vol. 37(13): 2895-2914.

McKendall Jr., A.R., Shang, J., and Kuppusamy, S. 2006. *Simulated annealing heuristics for the dynamic facility layout problem*. Computers and Operations Research, Vol. 33: 2431-2444.

McKendall Jr., A.R., and Shang, J. 2006. *Hybrid ant systems for the dynamic facility layout problem*. Computers and Operations Research, Vol. 33: 790-803.

McKendall Jr., A.R., and Hakobyan, A. 2010. *Heuristics for the dynamic facility layout problem with unequal-area departments*. European Journal of Operational Research, Vol. 201: 171-182.

McKendall Jr., A.R., and Liu, W.H. 2012. *New Tabu search heuristics for the dynamic facility layout problem*. International Journal of Production Research, Vol. 50(3), 867-878.

Meade, L.M., and Sarkis, J. 1999. *Analyzing Organizational Project Alternatives for Agile Manufacturing Processes: An Analytical Network*. International Journal of Production Research, Vol. 37: 241-261.

Meller, R.D. 1997. *The multi-bay manufacturing facility layout problem*. International Journal of Production Research, Vol. 35(5): 1229-1237.

Meller, R.D., Chen, W., and Sherali, H.D. 2007. *Applying the sequence-pair representation to optimal facility layout designs*. Operations Research Letters, Vol. 35: 651-659.

Meller, R.D., Kirkizoglu, Z., and Chen, W. 2010. *A new optimization model to support a bottom-up approach to facility design*. Computers and Operations Research, Vol. 37: 42-49.

Merker, J., and Wäscher, G. 1997. *Two new heuristic algorithms for the maximal planar layout problem*. OR Spectrum, Vol. 19: 131-137.

Mohamadghasemi, A., and Hadi-Vencheh, A. 2012. *An integrated synthetic value of fuzzy judgments and nonlinear programming methodology for ranking the facility layout patterns*. Computers and Industrial Engineering, Vol. 62: 342-348.

Moslemipour, G., Lee, T.S., and Rilling, D. 2012. *A review of intelligent approaches for designing dynamic and robust layouts in flexible manufacturing systems*. International Journal of Advanced Manufacturing Technology, Vol. 60: 11-27.

Moslemipour, G., and Lee, T.S. 2012. *Intelligent design of a dynamic machine layout in uncertain environment of flexible manufacturing systems*. Journal of Intelligent Manufacturing, Vol. 23: 1849-1860.

Murray, C.C., Smith, A.E., and Zhang, Z. 2013. *An efficient local search heuristic for the double row layout problem with asymmetric material flow*. International Journal of Production Research, Vol. 51(20): 6129-6139.

Muther, R. 1973. *Systematic Layout Planning*. Boston: Cahners Books.

Navidi, H., Bashiri, M., and Bidgoli, M.M. 2012. *A heuristic approach on the facility layout problem based on game theory*. International Journal of Production Research, Vol. 50(6): 1512-1527.

Niroomand, S., Hadi-Vencheh, A., Sahin, R., and Vizvári, B. 2015. *Modified migrating birds optimization algorithm for closed loop layout with exact distances in flexible manufacturing systems*. Expert Systems with Applications, Vol. 42: 6586-6597.

Nourelfath, M., Nahas, N., and Montreuil, B., 2007. *Coupling ant colony optimization and the extended great deluge algorithm for the discrete facility layout problem*. Engineering Optimization, Vol. 39(8): 953-968.

Onut, S., Kara, S.S., and Isik, E. 2009. *Long term supplier selection using a combined fuzzy MCDM approach: A case study for a telecommunication company*. Expert Systems with Applications, Vol. 36: 3887–3895.

Opricovic, S., and Tzeng, G.H. 2003. *Defuzzification within a multicriteria decision model*. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, Vol. 11(5): 635-652.

Opricovic, S., and Tzeng, G.H. 2004. *Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS*. European Journal of Operational Research, Vol. 156(2): 445–455.

Oussalah, M. 2002. *On the compatibility between defuzzification and fuzzy arithmetic operations*. Fuzzy Sets and Systems, Vol. 128(2): 247–260.

Ou-Yang, C., and Utamima, A. 2013. *Hybrid Estimation of Distribution Algorithm for solving Single Row Facility Layout Problem*. Computers and Industrial Engineering, Vol. 66: 95-103.

Ozyurt, D.B., and Realff, M. 1999. *Geographic and Process Information for Chemical Plant Layout Problems*. AIChE Journal, Vol. 45(10): 2161-2174.

Palubeckis, G. 2012. *A branch-and-bound algorithm for the single-row equidistant facility layout problem*. OR Spectrum, Vol. 34: 1-21.

Palubeckis, G. 2015. *Fast simulated annealing for single-row equidistant facility layout*. Applied Mathematics and Computation, Vol. 263: 287-301.

Pandey, P.C., Janewithayapun, S., and Hasin, M.A.A. 2000. *An integrated system for capacity planning and facility layout*. Production Planning and Control, Vol. 11(8): 742-753.

Parwananta, H., Maghfiroh, M.F.N., and Yu, V.F. 2013. *Two-Phase Genetic Algorithm for Solving the Paired Single Row Facility Layout Problem*. Industrial Engineering and Management Systems, Vol. 12(3): 181-189.

Paul, R.C., Asokan, P., and Prabhakar, V.I. 2006. *A solution to the facility layout problem having passages and inner structure walls using particle swarm optimization*. International Journal of Advanced Manufacturing Technology, Vol. 29: 766–771.

Pillai, V.M., Hunagund, I.B., and Krishnan, K.K. 2011. *Design of robust layout for Dynamic Plant Layout Problems*. Computers and Industrial Engineering, Vol. 61: 813-823.

Pourvaziri, H., and Naderi, B. 2014. *A hybrid multi-population genetic algorithm for the dynamic facility layout problem*. Applied Soft Computing, Vol. 24: 457-469.

Rajasekharan, M., Peters, B.A., and Yang, T. 1998. *A genetic algorithm for facility layout design in flexible manufacturing systems*. International Journal of Production Research, Vol. 36(1): 95-110.

Raminfar, R., Zulkifli, N., Vasili, M., and Hong, T.S. 2013. *An Integrated Model for Production Planning and Cell Formation in Cellular Manufacturing Systems*. Journal of Applied Mathematics, Vol. 2013: 1-10.

Ramkumar, A.S., Ponnambalam, S.G., and Jawahar, N. 2009. *A population-based hybrid ant system for quadratic assignment formulations in facility layout design*. International Journal of Advanced Manufacturing Technology, Vol. 44: 548–558.

Raoot, A.D., and Rakshit, A. 1991. *A "fuzzy" approach to facilities lay-out planning*. International Journal of Production Research, Vol. 29(4): 835-857.

Rastpour, A., and Esfahani, M.S. 2010. *Mathematical models for selection of optimal place and size of connections considering the time-value of money*. European Journal of Operational Research, Vol. 200: 764-773.

Río-Cidoncha, G.D., Martínez-Palacios, J., and Iglesias, J.E. 2007. *A multidisciplinary model for floorplan design*. International Journal of Production Research, Vol. 45(15): 3457-3476.

Ripon, K.S.N., Glette, K., Khan, K.N., Hovin, M., and Torresen, J. 2013. *Adaptive variable neighborhood search for solving multi-objective facility layout problems with unequal area facilities*. Swarm and Evolutionary Computation, Vol. 8: 1-12.

Saaty, T.L. 1980. *Analytic Herarchy Process*. New York: McGraw Hill.

Saaty, T.L. 1996. *Decision Making with Dependence and Feedback: The Analytic Network Process*. RWS Publications, Pittsburgh.

Saaty, T.L. 2001. *Decision making with dependence and feedback: The Analytic network process (2nd ed.)*. RWS Publications, Pittsburgh.

Saaty, T.L., and Vargas, L.G. 1998. *Diagnosis with dependent symptoms: Bayes theorem and the analytic network process*. Operations Research, Vol. 46(4): 491-502.

Sadrzadeh, A. 2012. *A genetic algorithm with the heuristic procedure to solve the multi-line layout problem*. Computers and Industrial Engineering, Vol. 62: 1055-1064.

Sahin, R., and Turkbey, O. 2009. *A new hybrid tabu-simulated annealing heuristic for the dynamic facility layout problem*. International Journal of Production Research, Vol. 47(24): 6855-6873.

Sahin, R., and Turkbey, O. 2009b. *A simulated annealing algorithm to find approximate Pareto optimal solutions for the multi-objective facility layout problem*. International Journal of Advanced Manufacturing Technology, Vol. 41: 1003-1018.

Sahin, R., Ertogral, K., and Turkbey, O. 2010. *A simulated annealing heuristic for the dynamic layout problem with budget constraint*. Computers and Industrial Engineering, Vol. 59: 308-313.

Sahin, R. 2011. *A simulated annealing algorithm for solving the bi-objective facility layout problem*. Expert Systems with Applications, Vol. 38: 4460-4465.

Salmani, M.H., Eshghi, K., and Neghabi, H. 2015. *A bi-objective MIP model for facility layout problem in uncertain environment*. International Journal of Advanced Manufacturing Technology, Vol. 81: 1563-1575.

Samarghandi, H., and Eshghi, K. 2010. *An efficient tabu algorithm for the single row facility layout problem*. European Journal of Operational Research, Vol. 205: 98-105.

Samarghandi, H., Taabayan, P., and Jahantigh, F.F. 2010. *A particle swarm optimization for the single row facility layout problem*. Computers and Industrial Engineering, Vol. 58: 529-534.

Samarghandi, H., and ElMekkawy, T.Y. 2012. *A meta-heuristic approach for solving the no-wait flow-shop problem*. International Journal of Production Research, Vol. 50(24): 7313-7326.

Samarghandi, H., Taabayan, P., and Behroozi, M. 2013. *Metaheuristics for fuzzy dynamic facility layout problem with unequal area constraints and closeness ratings*. International Journal of Advanced Manufacturing Technology, Vol. 67: 2701-2715.

Saraswat, A., Venkatadri, U., and Castillo, I. 2015. *A framework for multi-objective facility layout design*. Computers and Industrial Engineering, Vol. 90: 167-176.

Saravanan, M., and Arulkumar, P.V. 2015. *An artificial bee colony algorithm for design and optimize the fixed area layout problems*. International Journal of Advanced Manufacturing Technology, Vol. 78: 2079-2095.

Scholz, D., Petrick, A., and Domschke, W. 2009. *STaTS: A Slicing Tree and Tabu Search based heuristic for the unequal area facility layout problem*. European Journal of Operational Research, Vol. 197: 166-178.

Shayan, E., and Chittilappilly, A. 2004. *Genetic algorithm for facilities layout problems based on slicing tree structure*. International Journal of Production Research, Vol. 42(19): 4055-4067.

Shokri, H., Ashjari, B., Saberi, M., and Yoon, J.H. 2013. *An Integrated AHP–VIKOR Methodology for Facility Layout Desi*gn. Industrial Engineering and Management Systems, Vol. 12(4): 389-405.

Singh, S.P., and Sharma, R.R.K. 2006. *A review of different approaches to the facility layout problems*. International Journal of Advanced Manufacturing Technology, Vol. 30: 425-433.

Singh, S.P., and Sharma, R.R.K. 2008. *Two-level modified simulated annealing based approach for solving facility layout problem*. International Journal of Production Research, Vol. 46(13): 3563-3582.

Singh, S.P., and Singh, V.K. 2011. *Three-level AHP-based heuristic approach for a multi-objective facility layout problem*. International Journal of Production Research, Vol. 49(4): 1105-1125.

Sipper, D., and Bulfin Jr., R.L. 1997. *Production Planning, Control, and Integration*. McGraw-Hill

Sirinaovakul, B., and Limudomsuk, T. 2007. *Maximum weight matching and genetic algorithm for fixed-shape facility layout problem*. International Journal of Production Research, Vol. 45(12): 2655-2672.

Smith, A. 1776. *An Inquiry into the Nature and Causes of the Wealth of Nations*. Strahan and Cadell Printers, London.

Smith, J.M. 2010. *Robustness of state-dependent queues and material handling systems*. International Journal of Production Research, Vol. 48(16): 4631-4663.

Solimanpur, M., Vrat, P., and Shankar, R. 2004. *Ant colony optimization algorithm to the inter-cell layout problem in cellular manufacturing*. European Journal of Operational Research, Vol. 157: 592-606.

Solimanpur, M., Vrat, P., and Shankar, R. 2005. *An ant algorithm for the single row layout problem in flexible manufacturing systems*. Computers and Operations Research, Vol. 32: 583-598.

Solimanpur, M., and Jafari, A. 2008. *Optimal solution for the two-dimensional facility layout problem using a branch-and-bound algorithm*. Computers and Industrial Engineering, Vol. 55: 606-619.

Stevenson, W.J. 2009. *Operations Management*. 10th edition, McGraw Hill International Edition, New York.

Suhadak, N.S., Amit, N., and Ali, M.N. 2015. *Facility Layout for SME Food Industry via Value Stream Mapping and Simulation*. Procedia Economics and Finance, Vol. 31: 797-802.

Sukhotu, V., and Peters, B.A. 2012. *Modelling of material handling systems for facility design in manufacturing environments with jobspecific routing*. International Journal of Production Research, Vol. 50(24): 7285-7302.

Sushil. 2012. *Interpreting the interpretive structural model*. Global Journal of Flexible Systems Management, Vol. 13(2): 87–106.

Taghavi, A., and Murat, A. 2011. *A heuristic procedure for the integrated facility layout design and flow assignment problem*. Computers and Industrial Engineering, Vol. 61: 55-63.

Tam, K.Y., and Chan, S.K. 1998. *Solving facility layout problems with geometric constraints using parallel genetic algorithms: Experimentation and findings*. International Journal of Production Research, Vol. 36(12): 3253-3272.

Tari, F.G., and Neghabi, H. 2015. *A new linear adjacency approach for facility layout problem with unequal area departments*. Journal of Manufacturing Systems, Vol. 37: 93-103.

Tavakkoli-Moghaddam, R., Javadian, N., Javadi, B., and Safaei, N. 2007. *Design of a facility layout problem in cellular manufacturing systems with stochastic demands*. Applied Mathematics and Computation, Vol. 184: 721-728.

Taylor, F.W. 1911. *Principles of Scientific Management*. Harper and Row, New York.

Toloo, M., and Nalchigar, S. 2009. *A new integrated DEA model for finding most BCC-efficient DMU.* Applied Mathematical Modelling, Vol. 33: 597-604.

Toloo, M. 2012. *On finding the most BCC-efficient DMU: A new integrated MIP–DEA model*. Applied Mathematical Modelling, Vol. 36: 5515-5520.

Toloo, M. 2014. *An epsilon-free approach for finding the most efficient unit in DEA*. Applied Mathematical Modelling, Vol. 38: 3182-3192.

Toloo, M. 2015. *Alternative minimax model for finding the most efficient unit in data envelopment analysis*. Computers and Industrial Engineering, Vol. 81: 186-194.

Tompkins, J.A., White, J.A., Bozer, Y.A., Frazelle, E.H., Tanchoco, J.M.A., and Trevino, J. 1996. *Facilities planning*. New York: Wiley.

Tosun, U., Dokeroglu, T., and Cosar, A. 2013. *A robust Island Parallel Genetic Algorithm for the Quadratic Assignment Problem*. International Journal of Production Research, Vol. 51(14): 4117-4133.

Tseng, M.L. 2009. *A causal and effect decision making model of service quality expectation using grey-fuzzy DEMATEL approach*. Expert Systems with Applications, Vol. 36: 7738-7748.

Tsuchiya, K., Bharitkar, S., and Takefuji, Y. 1996. *A neural network approach to facility layout problems*. European Journal of Operational Research, Vol. 89: 556-563.

Tubaileh, A.S. 2014. *Layout of flexible manufacturing systems based on kinematic constraints of the autonomous material handling system*. International Journal of Advanced Manufacturing Technology, Vol. 74: 1521-1537.

Tunnukij, T., and Hicks, C. 2009. *An Enhanced Grouping Genetic Algorithm for solving the cell formation problem*. International Journal of Production Research, Vol. 47(7): 1989-2007.

Tuzkaya, G., Gulsun, B., Tuzkaya, U.R., Onut, S., and Bildik, E. 2013. *A comparative analysis of meta-heuristic approaches for facility layout design problem: a case study for an elevator manufacturer*. Journal of Intelligent Manufacturing, Vol. 24: 357-372.

U-Yeol, P., and Sung-Hoon, A. 2012. *Optimization Algorithms for Site Facility Layout Problems Using Self-Organizing Maps*. Journal of the Korea Institute of Building Construction, Vol. 12(6): 664-673.

Ulutas B.H., and Islier, A.A. 2009. *A clonal selection algorithm for dynamic facility layout problems*. Journal of Manufacturing Systems, Vol. 28: 123-131.

Ulutas, B.H., and Kulturel-Konak, S. 2012. *An artificial immune system based algorithm to solve unequal area facility layout problem*. Expert Systems with Applications, Vol. 39: 5384-5395.

Ulutas, B.H., and Kulturel-Konak, S. 2013. *Assessing hypermutation operators of a clonal selection algorithm for the unequal area facility layout problem*. Engineering Optimization, Vol. 45(3), 375-395.

Ulutas, B., and Islier, A.A. 2015. D*ynamic facility layout problem in footwear industry*. Journal of Manufacturing Systems, Vol. 36: 55-61.

Urban, T.L. 1998. *Solution procedures for the dynamic facility layout problem*. Annals of Operations Research, Vol. 76: 323-342.

Urban, T.L., Chiang, W.C., Russell, R.A. 2000. *The integrated machine allocation and layout problem*. International Journal of Production Research, Vol. 38(13): 2911-2930.

Ureten, S. 2013. *Üretim/İşlemler Yönetimi: Stratejik Kararlar ve Karar Modelleri*. Gözden Geçirilmiş 5. Baskı, Gazi Kitabevi, Ankara.

Vázquez-Román, R., Lee, J.H., Jung, S., and Mannan, M.S. 2010. *Optimal facility layout under toxic release in process facilities: A stochastic approach*. Computers and Chemical Engineering, Vol. 34: 122-133.

Vázquez-Román, R., Inchaurregui-Méndez, J.A., and Mannan, M.S. 2015. *A grid-based facilities allocation approach with safety and optimal heat exchanger networks synthesis*. Computers and Chemical Engineering, Vol. 80: 92-100.

Wang, T.Y., Lin, H.C., and Wu, K.B. 1998. *An Improved Simulated Annealing For Facility Layout Problems in Cellular Manufacturing Systems*. Computers and Industrial Engineering, Vol. 34(2): 309-319.

Wang, T.Y., Wu, K.B., and Liu, Y.W. 2001. *A Simulated Annealing Algorithm for facility layout problems under variable demand in Cellular Manufacturing Systems*. Computers in Industry, Vol. 46: 181-188.

Wang, K.J., and Chen, K.H. 2008. *An integrated facility-design model for the generator-manufacturing industry*. Production Planning & Control, Vol. 19(5): 475-485.

Wang, S., Zuo, X., Liu, X., Zhao, X., and Li, J. 2015. *Solving dynamic double row layout problem via combining simulated annealing and mathematical programming*. Applied Soft Computing, Vol. 37: 303-310.

Warfield, J. 1973. *On arranging elements of a hierarchy in graphic form*. IEEE Transactions: System, Man and Cybernetics, Vol. 2: 121–132.

Warfield, J. 1974. *Toward interpretation of complex structural models*. IEEE Transactions: System, Man and Cybernetics, Vol. 5: 405–417.

Wäscher, G., and Merker, J. 1997. *A comparative evaluation of heuristics for the adjacency problem in facility layout planning*. International Journal of Production Research, Vol. 35(2): 447-466.

Wei, G. 2009. *Uncertain linguistic hybrid geometric mean operator and its application to group decision making under uncertain linguistic environment*. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, Vol. 17(02): 251–267.

Wong, K.Y., and Komarudin. 2010. *Solving facility layout problems using Flexible Bay Structure representation and Ant System algorithm*. Expert Systems with Applications, Vol. 37: 5523-5527.

Wu, Y., and Appleton, E. 2002. *Integrated design of the block layout and aisle structure by simulated annealing*. International Journal of Production Research, Vol. 40(10): 2353-2365.

Wu, Y., and Appleton, E. 2002b. *The optimization of block layout and aisle structure by a genetic algorithm*. Computers and Industrial Engineering, Vol. 41: 371-387.

Wu, W.W., and Lee, Y.T. 2007. *Developing global managers' competencies using the fuzzy DEMATEL method*. Expert Systems with Applications, Vol. 32: 499-507.

Xiao, Y., Seo, Y., and Seo, M. 2013. *A two-step heuristic algorithm for layout design of unequal-sized facilities with input/output points*. International Journal of Production Research, Vol. 51(14): 4200-4222.

Xu, Z. 2004. *Uncertain linguistic aggregation operators based approach to multiple attribute group decision making under uncertain linguistic environment*. Information Sciences, Vol. 168(1): 171–184.

Xu, Z. 2006. *Approach based on the uncertain LOWG and induced uncertain LOWG operators to group decision making with uncertain multiplicative linguistic preference relations*. Decision Support Systems, Vol. 41(2): 488–499.

Xu, Y., and Da, Q. 2008. *A method for multiple attribute decision-making with incomplete weight information under uncertain linguistic environment*. Knowledge-Based Systems, Vol. 21(8): 837–841.

Yager, R.R., and Filev, D.P. 1994. *Essentials of fuzzy modeling and control*. New York: John Wiley and Sons.

Yalaoui, N., Mahdi, H., Amodeo, L., and Yalaoui, F. 2011. *A new approach for workshop design*. Journal of Intelligent Manufacturing, Vol. 22: 933-951.

Yang, T., and Kuo, C. 2003. *A hierarchical AHP/DEA methodology for the facilities layout design problem*. European Journal of Operational Research, Vol. 147: 128-136.

Yang, T., and Hung, C.C. 2007. *Multiple-attribute decision making methods for plant layout design problem*. Robotics and Computer-Integrated Manufacturing, Vol. 23: 126-137.

Yang, C.L., Chuang, S.P., Hsu, T.S. 2011. *A genetic algorithm for dynamic facility planning in job shop manufacturing*. International Journal of Advanced Manufacturing Technology, Vol. 52: 303-309.

Yang, L., Deuse, J., and Jiang, P. 2013. *Multiple-attribute decision-making approach for an energy-efficient facility layout design*. International Journal of Advanced Manufacturing Technology, Vol. 66: 795-807.

Ye, M., and Zhou, G. 2007. *A local genetic approach to multi-objective, facility layout problems with fixed aisles*. International Journal of Production Research, Vol. 45(22), 5243-5264.

Zadeh, L.A. 1965. *Fuzzy Sets*. Information and Control, Vol. 8: 338-353.

Zhang, G.Q., Xue, J., and Lai, K.K. 2000. *A genetic algorithm based heuristic for adjacent paper-reel layout problem*. International Journal of Production Research, Vol. 38(14): 3343-3356.

Zhang, M., Batta, R., and Nagi, R. 2011. *Designing manufacturing facility layouts to mitigate congestion*. IIE Transactions, Vol. 43(10): 689-702.

Zhang, Z., and Murray, C.C. 2012. *A corrected formulation for the double row layout problem*. International Journal of Production Research, Vol. 50(15): 4220-4223.

Zhao, T., and Tseng, C.L. 2007. *Flexible Facility Interior Layout: A Real Options Approach*. Journal of the Operational Research Society, Vol. 58: 729-739.

Zuo, X., Murray, C.C., and Smith, A.E. 2014. *Solving an Extended Double Row Layout Problem Using Multiobjective Tabu Search and Linear Programming*. IEEE Transactions on Automation Science and Engineering, Vol. 11(4): 1122-1132.

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