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The Great Seto Bridge is a series of double deck bridges connecting Okayama and Kagawa prefectures in Japan across a series of five small islands in the Seto Inland Sea. Built over the period 1978–88, it is one of the three routes of the Honshū–Shikoku Bridge Project connecting Honshū and Shikoku islands, and the only one with railroad connections included. With 13.1 kilometers (8.1 mi) two-tiered bridge, it ranks as one of the world's longest two-tiered bridge system. Crossing the bridge takes about 20 minutes by car or train. The ferry crossing before the bridge was built took about an hour. The bridges carry two lanes of highway traffic in each direction (Seto-Chūō Expressway) on the upper deck and one railway track in each direction (Seto-Ōhashi Line) on the lower deck. The lower deck was designed to accommodate Shinkansen services sharing with the Seto-Ōhashi Line on dual gauge track similar to the Seikan Tunnel.

https://www.ilikese.com/industry/traffic/bridge/sea-bridge/great-seto-bridge/

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Proposal for an Integrated Decision Support System for Bridge Type Selection during the Conceptual Design Phase

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Keywords

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Bridge Information Modeling
Infrastructure Management System
Decision Support System
Artificial Intelligence
Life-cycle Cost
Decision Makers

Abstract

Today, when it comes to selecting the most appropriate bridge type and defining its respective component and properties, no systematic procedure exists when the bridge is still in its conceptual design phase; selection is often based on the subjectivity of the decision-makers, which is regarded as a weakness in bridge project processes. A Decision Support System (DSS) that operates in an artificial intelligence (AI) environment and takes into account most of the relevant factors (e.g. acquisition cost, aesthetic appearance, and life-cycle cost (LCC)), is very much needed, in order to achieve decision consistency. The aim of the research addressed in this paper is to propose a methodology for developing systematic procedures that can help decision-makers select the most appropriate type of bridge, with its various components and parameters, in a given situation, as well as predict its LCC and other characteristics, such as the level of public satisfaction and environmental sustainability.

1. INTRODUCTION

Infrastructure management systems (IMS), in particular bridge management systems (BMS), have been pre-occupying decision-makers for many years, with various systems and commercial software (e.g. SQL, Oracle, Access, Delphi, and Power Builder) having been used throughout Europe and in countries in the Far East (Woodward, 2001). Many researchers and organizations work tirelessly to improve the decision support process as regards bridge type selection by developing new methodologies with the aim of meeting the demands of the respective bridge situation as much as possible. In all cases, the focus should be on what engineers need to consider when deciding which type of bridge to adopt; what parameters, factors, and matters of concern need to be taken into account, in order to avoid or minimize current and future shortcomings of the respective bridge, as the conceptual design phase of a bridge has a significant impact on the costs of the overall project, as also

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noted by Hendrickson (2008). Thus, the conceptual design phase of a bridge is of paramount importance as regards LCC optimization of the overall bridge project.

The research addressed in this paper is aimed at developing a DSS model that provides engineers with additional useful tools for selecting the most appropriate type of bridge, and its respective components, which leads to an optimization of the LCC of the respective bridge, and also meets other demands, such as aesthetic satisfaction and environmental protection. Thus, the objectives of the proposed methodology can be summarized as follows:

(a) to highlight the influence of human subjectivity on the decision-making process;
(b) to list and rank the potential alternatives in relation to their performance criteria;
(c) to ensure that equal and fair consideration is given to selected factors that are of influence on the decision-making process, using conventional decision-making approaches; and
(d) to develop a systematic methodology that, based on a relevant historical database and expert input, can be viewed as a guide for further use in any decision-making environment.

Thus, this research is aimed at reducing the subjectivity of decision-makers as regards bridge type selection by highlighting the factors that influence the decision. Using statistical methods, different subject-related factor types in combination with respective location-related factors are highlighted. Then, these factors are manipulated in an artificial intelligence (AI) environment, in order to find out how they influence the decision. Finally, various potential alternatives are evaluated based on the selected factors and according to the ranking of performance criteria. The reliability of the selected factors is checked and supported by a sensitivity analysis of the selected factors.

2. LITERATURE REVIEW

In order to have a clear understanding of bridge concepts, it is crucial to look at the history and development of bridge structures and the associated philosophies. Many references, reports, and dissertations on bridge architecture philosophies are available that give a well-informed insight into bridge philosophy, which is an integral part of this research (Tang, 2007).

Many references have indicated that bridge design embraces two phases: the conceptual and the analytical design phases (Miles & Moore, 1991; Chen Wai-Fah & Duan Lian, 2000). The analytical design phase is very well defined through the use of codes and formulas, while the conceptual design phase is not well defined. As regards the latter, the large number of studies conducted by various engineering firms and consultants have produced more or less different opinions, leading to different final decision outcomes (Smith et al., 1994 and Mahmoud, 2015). For instance, Thompson and Shepard (2000) proposed an inventory of elements that forms the basis for bridge inspection and maintenance tasks. The types of material used for bridges have their own specific influence; Smith et al. (1994) noted a number of material properties and their respective influence on bridge components. Smith noted a large number of factors that are of influence and should therefore be considered in the decision-making process as regards bridge type selection.

Other studies adopted the Analytical Hierarchy Process (AHP) to rank the key factors that have a significant impact on bridge type selection, on the basis of an official collection of data obtained for over thirteen hundred (1,300) highways. This collected data focused on non-structural factors that influence decisions as regards bridge materials. Choi (1993) grouped the factors that influence conceptual bridge design into two categories of design constraints: "Hard Constraints - HC" and "Soft Constraints - SC". Chen and Duan (2000) provided basic bridge parameters that take different factors into account: a) technical; b) functional; c) economical; d) construction; and e) materials and their respective geometric dimensions: these parameters define the quality of the bridge structure.

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Bridgeman (2012) believes that before starting any bridge design, a significant amount of data should first be available, such as a site map that shows all the obstacles to be bridged; a longitudinal cross-section of the concerned bridge to illustrate the required distances; factors affecting the width of the bridge (e.g. capacity, sidewalks, safety railings); soil condition and soil difficulties; local conditions and buildability factors; climatic and environmental conditions; topography of the environment and aesthetic requirements. A totally different approach was noted by Hotaling et al. (2015), who examined a specialty in the area of decision making known as dynamic decision making, which is characterized by the fact that, in order to control and optimize the performance of a dynamic stochastic system, the decision-maker chooses between different actions at different points in time. The aspect of aesthetics was discussed by Moore et al. (1996) with reference to public opinion, rules for the acquisition, collection, and dissemination of a large number of subjective opinions in bridge aesthetics. Marzook et al. (2013) introduced a list of key factors that influence the sustainability of bridge projects, which was determined through interviews and surveys.

Further, artificial intelligence (AI) has been used to solve problems that are difficult to solve using conventional mathematical methods. Many researchers have found labeling methods to solve some aspects of *transportation* problems and ease the decision-making process while executing bridge replacement or maintenance plans by applying artificial intelligence (AI) paradigms to improve the efficiency, safety, and environmental sustainability of transportation systems (Sadek et al., 2003). For humans, as well as other living beings, the brain's neural network is considered to be the basic functional source of intelligence, encompassing perception, cognition, and learning (Toshinori, 2008). Many other models and methods exist (e.g. Quality Function Deployment (QFD), Knowledge-Based Systems (KBS) (Arain and Pheng, 2006), Case-Based Reasoning (CBR) (Dogan et al., 2006), Expert Systems (ES), Fuzzy Systems (FS) (Takagi, 1997), Genetic Algorithms (GA) (Toshinori, 2008)) that have already established themselves in the transportation sector and shown to be particularly useful in design decisions.

Finally, based on what has already been uncovered, a number of weaknesses have been identified: (1) there is no clear systematic method for defining the factors to be considered in the conceptual design phase (Smith et al., 1994); (2) technical judgments and subjectivity have been widely adopted without there being any consistent rules (Yao et al., 2011); (3) no flexibility can be observed in existing methods that are limited to specific cases and constrained conditions (Dekker, 2000); (4) there is no Bridge Information Modeling (BrIM) implementation in the conceptual design phase (Herman et al., 2008); (5) there exist discrepancies between different expert opinions (Nedev and Khan, 2011).

3. RESEARCH METHODOLOGY

Conceptual design is the first step in any type of structural design and, thus, also that of bridges. Bridges are a type of structure that must be evaluated well before proceeding with theoretical analysis and detailed design. When selecting bridge systems, the respective materials, proportions, dimensions, foundations, aesthetics and other factors, such as the prevailing surrounding landscape and environmental aspects, are taken into account in the conceptual design process, which is the first of six phases in the life of a bridge.

This paper looks at research that has been conducted to develop a Decision Support System (DSS) methodology for use in the "conceptual" design phase of bridges, thereby taking into account various criteria: technical, functional and economic, as well as the material and the geometric dimensions of the respective bridge system. To evaluate the influencing factors, they are divided into two main categories: hard factors and soft factors. Hard factors include, for instance, characteristics of the respective site, capacity and complexity of construction, while the soft factors may include those that

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define the level of performance (e.g. cost-benefit) assessment, aesthetic ranking and environmental impact level).

The main aim of the research is to attempt to emphasize and/or minimize subjectivity in decision-making and, thus, reduce and limit its effects; the purpose is to go from the ambiguity of subjectivity in decision-making to an accurate well-founded decision-making process, i.e. to control the said subjectivity, in order to reduce errors and/or inaccuracies when the bridge is still in its conceptual design phase.

To this end, this research aims to define a DSS methodology that offers an integrated, structured approach that takes into account a large number of influencing factors and constraints. The influencing factors are defined and evaluated by the DSS-user based on available data from existing projects, and taken into account to create a relevant data module.

3.1 Models and Methods

Structural design problems are often complex, and synthesizing a good solution requires human qualities, such as technical judgment, intuition, experience, and creative skills. The proposed DSS embraces three steps:

(a) building an accurate library of bridge types and their respective components by structuring the required data forms that store appropriate information from previous projects;
(b) defining a suitable model that allows the information to be handled in a user-friendly manner, and produces a reliable solution output; and
(c) using BrIM concepts and tools to provide a visualization of the solution output produced.

The performance of a bridge is predicted and assessed based on the evaluation of the following factors: Aesthetics, LCC, Environment and public satisfaction/capacity and services. This is based on existing bridges that have the same conditions as the proposed one. The DSS is set up in such a manner so as to make the parameters of the model as flexible as possible to allow users to include other parameters and conditions and to show how those parameters affect the DSS outputs. Dot-scale converters are introduced to convert some aspects, such as soil behavior, into numbers.

3.2 DSS Framework and Its Components

The main components of the DSS are: the data module, which contains the data on the various bridge types and their respective components (related to their geometric parameters) and the parameters that influence the performance of the respective bridges (such as overpass area, soil behavior, bridge capacity, number of lanes, number of spans, total length), the DSS engine, which contains input and output parameters and, finally, the BrIM process to ensure the correctness and appropriateness of the decisions made by the decision-makers correspond with those made by the DSS engine.

In Figure 1, the DSS Framework configuration is shown schematically. The DSS begins with collecting the necessary information from suitable resources that is to be included in the data module. Following the creation of the data frame, the necessary analysis is carried out, in order to convert the collected data into suitable numerical values that are to be implemented in the DSS engine. The DSS engine, which works in artificial intelligence (AI) environment (will be explained in more detail in the next sections), runs under this input data in order to provide the corresponding output values. The output values are verified and analyzed simultaneously through two processes: (1) through technical evaluation; and (2) through the implementation of the output values in BrIM tools. Finally, the decision is made whether to accept the output or to request any changes to be made.

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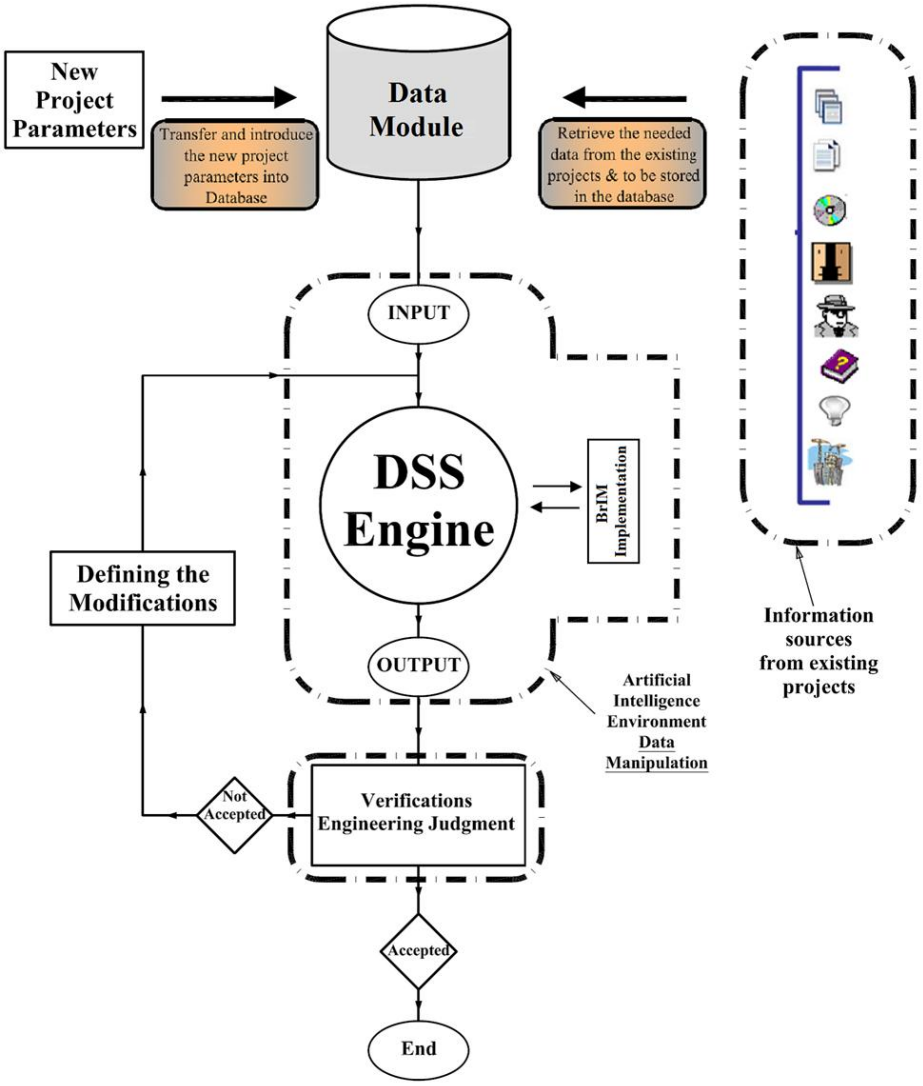

Figure 1. DSS framework

A data structure is a collection of information organized in such a manner that it can be easily accessed, managed and updated. In computer science, data is classified according to its organizational approach. The most widely used approach is the relational database, a tabular database in which data is defined in such a manner that it can be reorganized and retrieved in various ways. Figure 2 describes the relevant information that must be contained in a well-structured data frame so that, after appropriate analysis, it provides the correct values for the DSS engine. As Figure 2 reveals, the input criteria and their respective descriptions are grouped under the bridge information set, which is divided into two main groups:

(a) bridge components: in this group, the information collected is subdivided into:
  (i) administrative information (e.g. project name, project identification number, brief project description); and
  (ii) geometric and structure information, which describes the respective bridge elements, such as bridge type (BT), column type (CT), foundation type (FT), deck type (DT).

(b) bridge characteristics and parameters: in this group, the influencing factors are divided into:
  (i) controlled and uncontrolled variables, which are represented as hard factors; and
  (ii) criteria according to the values of which a decision is made, so-called output criteria (cost (LCC), Environmental Impact Rate (EIR), Aesthetic Impact Rate (AIR)), which are represented as soft factors.

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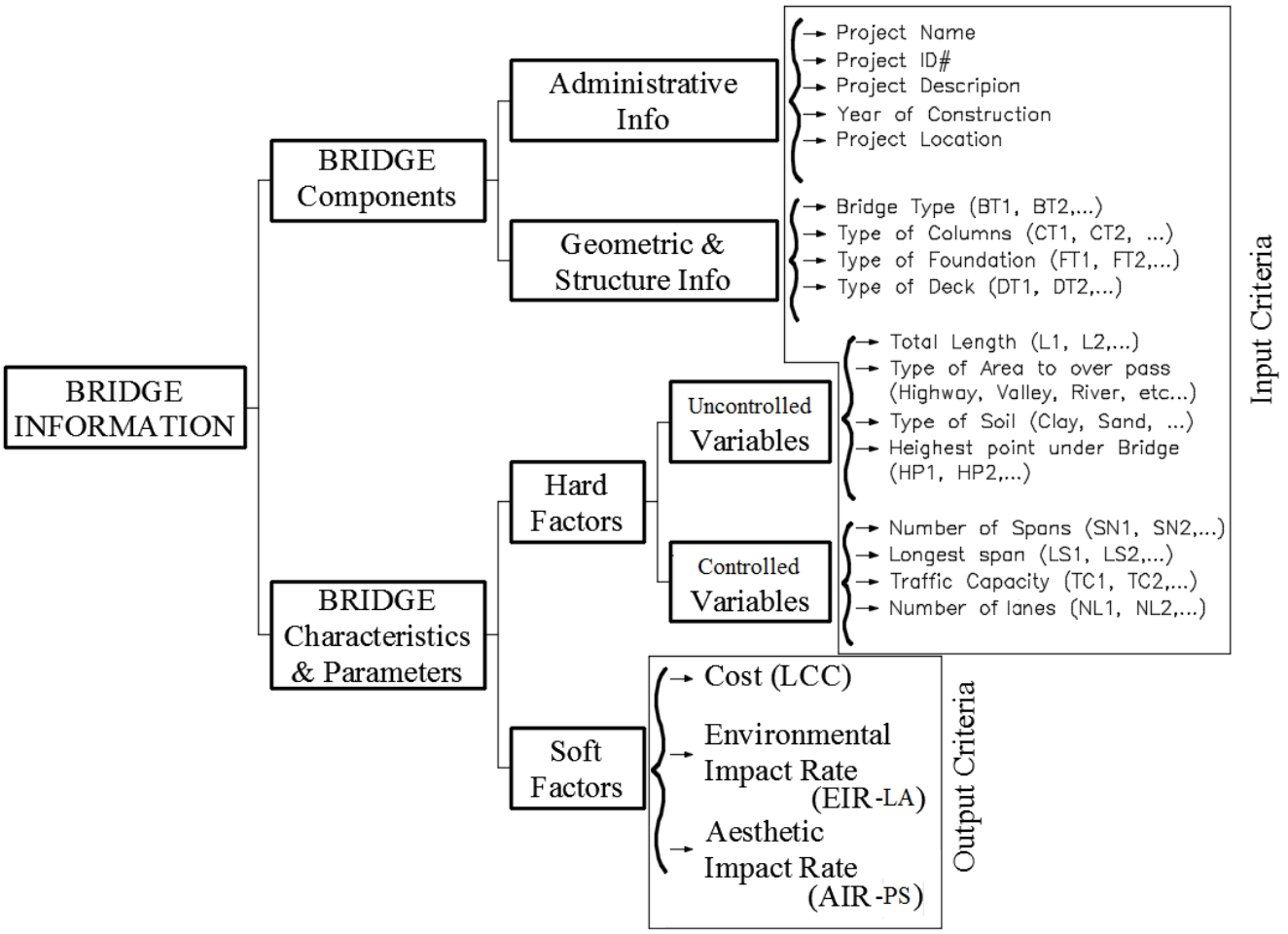

Figure 2. Bridge information algorithm

Subsequently, all criteria are divided into five categories: (I) Administrative Information, (II) Geometric and Structure Information, (III) Uncontrolled Variables, (IV) Controlled Variables, and (V) Soft Factors; it should be noted that the criteria listed in this research section may be the subject of some additional or retained elements later on in the final DSS development process. Some factors are defined by linguistic information, which must be converted into numerical values by point scales that are defined separately for each type of criteria. The point scale method is widely used to convert linguistic information into numerical data for ease of use. For the existing bridge projects, all the criteria values listed under the controlled and uncontrolled variables are defined according to the real and existing situation of the respective bridges, while for the new bridge project that is being analyzed, the criteria values found under the controlled variables are based on the results derived by the designer whereas the uncontrolled variables are considered immutable values with respect to the bridge position constraints. Among the various Category II factors, (a) Environmental Impact Rate (EIR) and (b) Aesthetic Impact Rate (AIR) are two factors that must be assessed for each bridge as a function of many parameters.

The Environmental Impact Rate (EIR) is determined in the conceptual design phase after the bridge location has been determined with other related factors. Based on the "WAS" factors implemented in a Quality Function Deployment (QFD) system, the EIR is calculated based on equation [Eq.1], which relates to two factors:

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(1) the indicator of the main impacts (MIi) related to CO_2 emissions; and
(2) the indicator of the Surround Impact (SIi), which includes factors related to the location of the bridge and neighboring people.

$$\mathbf{EIR_i = A.(MI_i) + B.(SI_i)} \quad \textbf{[Eq.1]}$$

where i is a reference number-related existing project ID; A is a percentage importance factor that is assigned to the MI by the designer; B is a percentage importance factor that is assigned to the SI by the designer, where A + B = 100%. The (MIi) values should be obtained from the collected data and assigned to the existing bridges; otherwise, diagrams and values should be implemented in the model element, while the methodology to be assessed (MIi) is adopted from existing and/or future studies that provide a methodology for counting the environmental impact of a bridge based on the materials used and energy consumption. The final Values of (MIi) should be presented on a scale of 1-99. The values of (SIi) are calculated based on the defined factors implemented by "WAS" in a Quality Function Deployment (QFD) system. The mentioned factors are given an importance rating (IRj) according to their importance from the point of view of the decision-maker. The elements of the QFD are the existing bridges, and for each bridge case a value (Vj, i) on a point scale (e.g. 1-10) and according to the degree of the assigned correlation between existing bridges and WAS. The roof part represents the correlation that exists between elements and this QFD part is omitted from our study. The "n" bridges are arranged according to the "m" factors in the first columns. After entering the required data, the bottom two lines are calculated as follows:

Raw Score:
$$\boldsymbol{RS_i = \sum_{j=1}^{m} V_{j,i} \times IR_j} \quad \textbf{[Eq.2]}$$

Surround Impact:
$$SI_i = INT\{\frac{RS_i - MIN[RS_i]}{\frac{MAX[RS_i] - MIN[RS_i]}{98}} + 1\} \quad \textbf{[Eq.3]}$$

Equation [Eq. 3] aims to adapt the (SIi) values to a 99-point scale based on the normalization method.

Like the Environmental Impact Rate (EIR) value, the Aesthetic Impact Rate (AIR) must also be reported for the use of the proposed DSS. A methodology for evaluating the Aesthetic Impact Rate (AIR) that is based on an innovative computational decision support tool is proposed, as most of the published work on bridge aesthetics is based on the judgment of bridge designers and some rudimentary calculations regarding bridge element dimensions and the location of the bridge, as well as the surrounding area. The Aesthetic Impact Rate (AIR) values, which are defined on the basis of various factors, are divided into the following 5 categories:

(1) **Proportion and Geometry**: ensuring that the bridge deck looks reasonably slim and is in keeping appropriate to the shape of the support pillars (i.e. round or rectangular);

(2) **Environment**: ensuring that the bridge is in harmony with its surroundings and that the bridges on a road have visual compatibility with one another;

(3) **Structural Harmony**: this refers to the load-bearing capacity of the bridge and the way in which the load is transferred from element to another (should be obvious and should "look right", e.g. bridge);

(4) **Attention Focus**: this refers to the identified problem with two-field bridges that the eye cannot focus on (bridges with an odd number of fields do not seem to suffer from this problem);

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(5) **Weathering and Surface Properties**: Sustainability elements to be suitable and compatible with the overall bridge visual aspect.

Many more categories can be added by the designers during the development process and/or even later. After screening the appropriate factors, a QFD system could be used, in the same manner as previously described for the Environmental Impact Rate (EIR), to assess the Aesthetic Impact Rate (AIR) values for each bridge case, which can be calculated using the following relationship:

$$\mathbf{AIR_j} = \sum_{i=1}^{n} I_i * V_i \qquad \textbf{[Eq.4]}$$

where:

j is an ID reference number for the existing project,
i are parameter indices, and
V is a harmonic measure that exists between the bridge and its surroundings.

A model for evaluating the Aesthetic Impact Rate (AIR) value will be created and included as a set in the data file in the DSS and used when necessary; this model will relate to many research projects and methods already executed. The aim of the proposed DSS is to provide values for some performance factors that are defined as soft factors (output criteria). These soft factors can be Life Cycle Cost (LCC), Environmental Impact Rate (EIR) – assessment by local authorities, and Aesthetic Impact Rate (AIR) – public satisfaction.

After most of the criteria categories have been defined, a structure for the data module is defined as presented in Figure 3. The main component of the data framework is the Library block. The Library contains five defined categories, and the information contained in these categories (factors and variable definitions) is created from the resources according to the information available.

After the Library has been set up (covering all possible factors for the 5 categories), values (numeric and/or linguistic) are assigned to the Library items to define all of the criteria contained in the primary data module. Microsoft Excel (and/or Access) software is the tool that is used to computerize the data process content. It provides real control over the data, in that it allows data to be collected, sorted, analyzed, summarized, as well as the results to be reported. It combines data from different files, so that information never has to be entered twice. It makes data entry more efficient and accurate.

MS Excel will be much more than just a list or a table, because it will also contain the defined models (e.g. linguistic converter, point scale, QFD system) that aim to analyze the information and make it available in a suitable and usable format.

For the DSS engine, the Artificial Neural Network (ANN) is seen as its main component. An artificial intelligence (AI) network consists of a pool of simple processing units that communicate with each other by sending signals to one another over various weighted links. A number of main aspects of a parallel distributed model can be distinguished by the number of processing units (neurons), the state of each neuron (as output), the connection between the units (input, hidden and output neurons), the rules of propagation, and the activation function that the new activation level is determined based on the actual input and the current activation, the external input, the method of obtaining information (stored in a data structure and then implemented in the ANN learning rules) and the environment in which the system must function.

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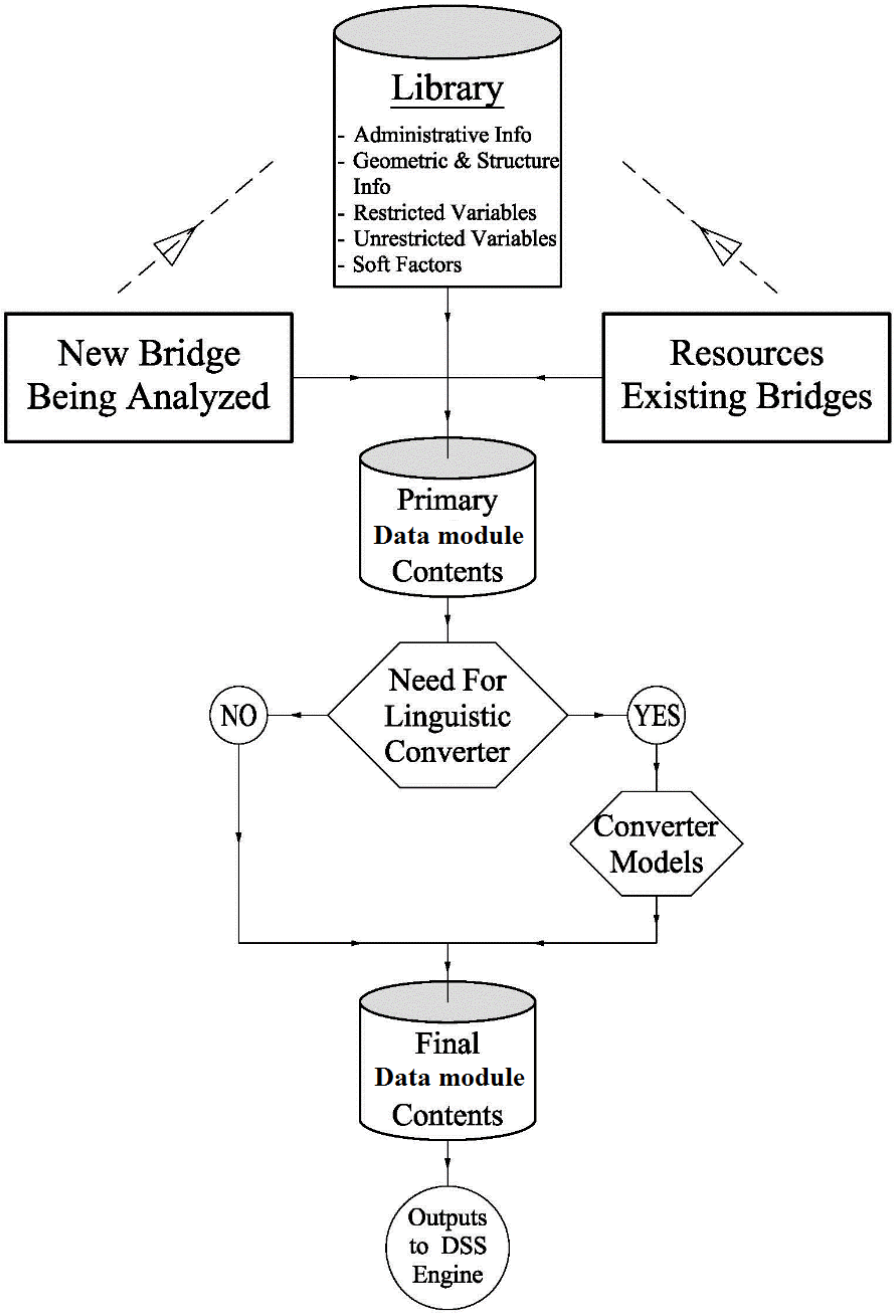

Figure 3. Global data framework

There are three types of layers within ANN systems: the Input Layer, which receives data from outside the neural network; the Output Layer, which sends data from the neural network; and Hidden Layers, the input and output signals of which remain within the neural network. The adaptation process using the ANN system is based on its main features:

(1) Backpropagation, which are learning rules to be followed;
(2) The number of hidden layers/neurons per layer, which are to be suitably defined; and
(3) The selection of the activation function for the purpose of solution convergence.

The Input Layer covers three categories:

(1) Geometric and Structural Information;
(2) Uncontrolled Variables; and

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(3) Controlled Variables.

The selected factors to be included in these categories is selected on the basis of expert opinions obtained through interviews and questionnaires in which the factors are proposed, rated and appropriately selected, thereby taking into account the specifics of the respective bridge site, as well as the available data that should be used. The values assigned to the input neurons are taken from the corresponding tables in the data module according to existing bridge cases, which are used for the learning process of the network.

The Output Layer, which represents the soft factors, is defined as the "performance criterion"; it is also selected on the basis of expert opinions obtained through interviews and questionnaires. Hidden Layers, which are linked by the weights (Wik, Wkl, Wlj) and a corresponding activation function (sigmoid functions F1 and F2). One or two hidden layers are enclosed with a defined number of neurons according to the number of input and output neurons and patterns. The mentioned weights and the hidden neuron values are defined after the network training based on the existing cases, which should be considered and used in the specified methodology. Based on the previous and existing bridge cases, a training process is started to generate the appropriate weights. Sample sets are selected to test the results.

As soon as all parameters of the ANN are clearly defined, the data is processed for a new case to be implemented in the ANN, in order to obtain the required results. The data of Categories 3 and 4 is well recognized for the new case due to the constraints related to the project location, whereas the data of Category 5 is generated by the networks and a decision is made based on the analysis of their values. That leaves the data of Category 2. The method for determining the values of this data category is based on a statistical study in which different alternatives are defined on the basis of different values that could be assigned to the factors.

Another method could also be used in which the values for the appropriate alternatives are defined based on the run for a "first order" of the ANN by considering the factors of Categories 3 and 4 as input data, and those of Category 2 as output data from ANN; the latter method is used in this proposed DSS. Based on the existing bridge cases, diagrams are created for all parameters, in order to retrieve suitable values for the ANN implementation. In this way, the criteria values of Category 2 are selected according to a systematic procedure.

3.3 BrIM Tools and Sensitivity Analysis

Geometric (covering the architectural elements) and structural (regarding the resistance of the structural elements) factors are implemented by commercial software tools used by the construction industry to control and facilitate the tasks of the engineer. These tools receive the results from the DSS engine and transfer them to the real environment. The decision-makers (engineers) verify all bridge aspects already extracted from the input and output data of the DSS engine and carry out the verification via the project visualization using a 3D model; then, a decision by the decision-maker is taken into account. Either the extracted results are acceptable, or they should be rejected or changed. In this case, another iteration must be started.

As described in the previous sections, the DSS is based on many criteria (Categories 2, 3 and 4) that influence the results (criteria from Category 5). In order to check the influence of each input criterion on the results, a sensitivity analysis (SA) is carried out, in order to understand the relationships between input and output criteria.

The importance of the SA is also that it examines how the uncertainty in the output of the DSS can be distributed across various sources of uncertainty in its inputs, in that the SA will identify the DSS

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inputs that cause significant uncertainty in the output, in order to reduce non-conformity. Further, for each output value provided by the DSS engine, a realistic level (LR) is analyzed based on diagrams created from the sensitivity analysis. This interpretation aims to quantify the extent to which the results are realistic. This proposed methodology is based on a comparison process between the ratio of the estimated to the actual values of a certain criterion (from Category 5) from an existing case with the ratio of the estimated value to the criterion value specified by the DSS engine for a specific case. Through this comparison, a tool may be found that enables the extent to which the output values make sense to be assessed. To this end, the proposed methodology is intended to help the experts to convince themselves first and then convince others when there are doubts or contradictions in their opinions and decisions based on a scientific and systematic methodology. The above instruments could be seen as an argument to defend the expert's decision and convince others.

The results of the described DSS are intended to serve as a guide for a new type of tool that is to be adapted and later improved through additional examinations and tests. Based on the artificial intelligence (AI) environment, a systematic methodology is provided that helps decision-makers to make their decision as regards bridge type selection in the conceptual design phase, based on and taking into account the performance (e.g. costs, environment, aesthetics) of existing bridges, with the aim to convert the high level of subjectivity into objectivity for any conceptual bridge design process, in order to increase the objectivity as compared to the subjectivity of the decision makers.

4. DSS DEVELOPMENT

4.1 Data Structure and Analysis

The focus of the research described in this paper is to propose an approach to determining the appropriate type of bridge based on various performance indicators. Indeed, there are many factors to consider in this part, with respect to the influencing factors and the performance factors that are identified by performance criteria. In addition, an analysis is carried out in this paper by selecting the appropriate factors to determine the alternatives and evaluate their performance. After selecting the appropriate factors, alternatives are defined. Each alternative is analyzed to rank the proposed alternatives and identify their performance. Since the proposed DSS is aimed at reducing subjectivity and move further towards objectivity in decision-making, it is important to provide a detailed methodology known as Flexible Methodology to help the decision-maker make changes during any part of the DSS, and observe their respective effects. Figure 4 shows the three components to be adjusted and analyzed that define the different parts of the DSS delivered.

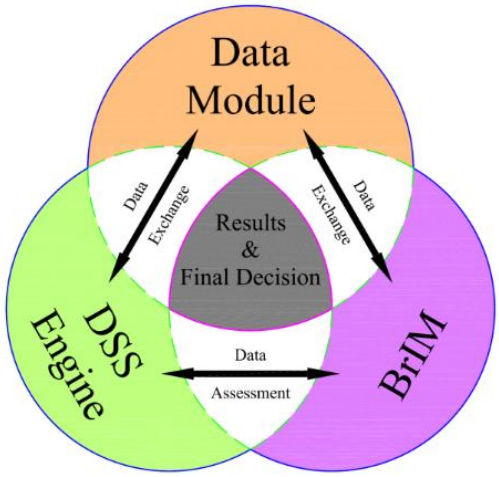

Figure 4. Interconnection of DSS components

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The data module frame, with its various sections and the relevant gathered information, is structured as follows:

(1) influencing factors are established and grouped into five categories;
(2) an expert and professional questionnaire is conducted to define the factors mentioned;
(3) the appropriate values for the foregoing factors are defined as follows:
    (a) numerical information collected directly from existing bridges through simple investigation and data search;
    (b) linguistic information (e.g. bridge type, soil type) that requires a conversion;
    (c) formula creation to define a number of other variables (e.g. EIR, AIR, AIR-PS);
(4) a complete data plan is established;
(5) statistical analyzes are carried out for two purposes:
    (i) to highlight the homogeneity/heterogeneity of the data; and
    (ii) to provide guidance to the decision-maker as to what alternatives might be proposed based on existing bridge cases;
(6) based on existing bridge cases, the ANN is structured and executed in order to extract the performance of each alternative; and
(7) factors that are considered input neurons and the factors that are considered as output (performance criteria) are used in the final run in order to evaluate the performance of the decision.

Given that special features must be observed for each region under study, a questionnaire is then sent to public and private bodies that are involved in bridge construction, bridge management and bridge design, in order to obtain their opinion on the common factors that have the greatest influence on their decision-making. In order to organize the factors, different categories are defined to distinguish between different types of factors that are known to be related to bridge projects (existing or under construction). The first category includes administrative information: bridge “ID”, bridge name “BN”, bridge location “BL”, and any other factor that could be useful. This information is made available when needed by storing it in a data frame to be suitable for many projects with different locations and years of construction. Two further categories (Categories II & V) define the alternatives and their performance indicators, and present a number of results for the final decision. Category II factors, entitled “Geometric and Structural Information”, includes those that define the bridge components. The following bridge elements are shown for a specified bridge: bridge identity “ID”; bridge type "BT", column type "CT", foundation type "FT". All of these factors with their associated values are provided for various existing bridge projects, as well as for proposed alternatives for new projects. In the case of existing bridges, the values assigned to the factors in Category II are collected from the real situation. For a new bridge to be examined, the relevant values are assigned on the basis of the proposed alternatives and from the Bridge Infrastructure Management (BrIM) analysis after implementation in the corresponding tools. Category V variables are collected from existing bridge cases based on their performance level; for a new bridge to be examined, the variables are extracted from the DSS engine, which works in an ANN environment. The factors presented in Category V are known as performance indicators. Suitable factors defined as performance indicators are, for instance: actual acquisition costs - PV "IC", operating and maintenance costs over 100 years "OC".

In addition to the performance indicator factors, there remain two categories of factors that are defined by the aforementioned questionnaire; these categories are: (a) Category III, known as "Uncontrolled Variables", which include the "Immutable Variables" that are automatically recorded once the location of the bridge has been proposed; (b) Category IV, known as “Controlled Variables”, which include the “Changeable Variables” that could be modified to achieve an optimal solution. Categories III, IV and V are divided into two main types of factors: (i) Hard Constraints, which cover Categories III and IV, and (ii) Soft Constraints, for Category V. In addition, the opinions of the experts are gathered regarding the

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factors that influence the performance of the selected bridge alternative. Based on the experts' opinions, a simple evaluation is carried out to classify the various factors, using the following equation (Eq. 5).

$$RFC_j = \frac{\sum_{i=1}^{n} R_{ij}}{\sum_{j=1}^{m}\sum_{i=1}^{n} R_{ij}} \quad \text{(Refer to Tables 4 to 6)} \quad \textbf{[Eq. 5]}$$

where:

n	is the number of participants of the questionnaire Q01
i	indicates a specific participant
m	is the number of factors considered
j	indicates a specific factor
R_{ij}	is factor j of participant i
RFC_j	is the rate value for factor j

The decision-maker will consider the appropriate factors based on their ranking RFCj. The aforementioned procedure highlights the factors to be considered in Categories III, IV and V. The factors embedded in Category I are easy to define, because they represent administrative information and do not require any technical knowledge. For the Category II, bridge components are defined according to the required and proposed details of the selected bridge alternatives. In general, the following factors are considered in Category II, with the flexibility to add or *reduce* related factors: Bridge Type (BT), Column Type (CT), Deck Type (DT), Foundation Type (FT), and Material Type (MT). In addition to these factors, others can also be considered, such as: Concrete Volume (CV), Industrial Steel Weight (ISW), exposed concrete surface (CS), and exposed concrete surface (SS), which will be retrieved following the implementation of the alternatives in the BrIM tools. In addition, the Estimated Initial Costs (EIC) calculated using the traditional method could also be taken into account. Further, two other factors, Environment Impact Rate (EIR) and Aesthetic Impact Rate (AIR), can also be calculated and taken into account. Three types of variables are considered: (i) those variables that can be defined automatically without the need for interpretation, since they are numerical values (i.e. total bridge length (TL), number of fields (NL), maximum load (ML), maximum speed (MS)); (ii) factors such as the Environmental Impact Rate (EIR), the Aesthetic Impact Rate (AIR); these factors require formulation in order to be assessed; (iii) a linguistic converter model that converts alphabetic variables into numeric variables. In the conceptual design phase of bridges, parameters that affect the environment must be verified. This is due to the lack of detailed construction drawings, construction procedures and equipment required. Thus, the analysis in this phase is based on the estimation of the CO_2 emissions by considering the energy consumption and its effects on the environment by indirectly taking into account the amount of material used according to the equation (Eq. 6):

$$EIR_i = ANA_{Ni} + CV_{Ni} + ISW_{Ni} \quad \textbf{[Eq. 6]}$$

where:

ANA_N	Normalized Factor [1-10] related to Affected Natural Area
CV_N	Normalized Factor [1-10] related to the Concrete Volume
ISW_N	Normalized Factor [1-10] related to Industrial Steel Weight
i	Bridge ID

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The factors ANA_N, CV_N and ISW_N have to be evaluated for each bridge alternative based on the following normalization procedure:

$$\left.\begin{array}{ccccc} \text{Min}[ANA/TBA]_i & < & [ANA/TBA]_i & < & \text{Max}[ANA/TBA]_i \\ 1 & < & ANA_{Ni} & < & 10 \end{array}\right\}$$

$$\rightarrow \quad ANA_{Ni} = \frac{[ANA/TBA]_i - MIN[ANA/TBA]_i}{\frac{MAX[ANA/TBA]_i - MIN[ANA/TBA]_i}{9}} + 1\} \qquad \text{[Eq.6a]}$$

$$\rightarrow \quad ISW_{Ni} = \frac{[ISW/TBA]_i - MIN[ISW/TBA]_i}{\frac{MAX[ISW/TBA]_i - MIN[ISW/TBA]_i}{9}} + 1\} \qquad \text{[Eq.6b]}$$

$$\rightarrow \quad CV_{Ni} = \frac{[CV/TBA]_i - MIN[CV/TBA]_i}{\frac{MAX[CV/TBA]_i - MIN[CV/TBA]_i}{9}} + 1\} \qquad \text{[Eq.6c]}$$

where:

ANA	Affected Natural Area (m^2)
TBA	Total Bridge Area (m^2)
CV	Total Concrete Volume (m^3)
ISW	Total Industrial Steel Weight (T)
EIR	Environment Impact Rate

A method using the given parameters described by the Maryland Department of Transportation (2005) is used for aesthetic evaluation. Among these parameters, the following are considered: (1) the ratio of deck span to depth; (2) the ratio of deck span to pillar height; (3) the ratio of deck depth to pillar width; (4) deck curvature in height; (5) deck elevation; (6) bridge skew angle; (7) integrity to the surrounding topography; (8) structural impression (strength through shape); (9) clear display; (10) lighting, shadows; (11) relationship to the substructure; (12) pillar dimension ratios; (13) color and textures; (14) consistency of architectural elements.

After highlighting the Factors/components, two values must be identified for each one: firstly, "I", the importance factor, rated between 1 and 10, which defines the level of importance of the respective feature for the decision-maker; and, secondly, the "V" factor, which helps to determine the harmonic state that exists between the bridge and its surroundings. For the expression of Aesthetic Impact Rate (AIR), the equation (Eq. 7) is used to check the bridge performance from an Aesthetic point view:

$$\left.\begin{array}{ccccc} 14 & < & \Sigma(I_i * V_i) & < & 1400 \\ 1 & < & AIR & < & 10 \end{array}\right\}$$

$$\rightarrow \quad AIR = INT\left[\left(\frac{(\sum_{i=1}^{14} I_i * V_i) - 14}{1386}\right) * 9 + 1\right] \qquad \text{[Eq.7]}$$

where:

INT ( )	is the Integer Function
AIR	Aesthetic Impact Rate – Category II

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The above formula is used to categorize the results between 1 and 10, with 10 referring to the most important factor in bridge aesthetics. One of the performance criteria is aesthetic behavior from the viewpoint of public satisfaction. A questionnaire will be created to assess public satisfaction with the aesthetic appearance of existing bridges. Many aesthetically relevant features needed to be checked. The following features are examined and assessed using the questionnaire: (1) proportion and geometry; (2) environment; (3) structural harmony; (4) attention focus; (5) weathering and surface quality.

Subsequently, all public questionnaires are compiled and evaluated using a linear interpolation assumption according to equation 8 (Eq.8), in order to estimate the "AIR-PSj" for each existing bridge that contain values of between 1 and 10 (10 is assigned to the design if fully satisfied). The importance rating "I" and the value "V" are also highlighted.

$$AIR-PS_j = INT\left(\frac{\sum_{i=1}^{n} I_i * V_i}{495} * 9 + 1\right) \quad \textbf{[Eq.8]}$$

where:

INT ( )	is the Integer Function
AIR-PS$_j$	Aesthetic Impact Rate – Public Satisfaction - Category V
j	Related to one of "m" persons investigated for a specified bridge

Then, for a specified Bridge, the "AIR-PS" is given by the equation 9 (**Eq.9)**:

$$AIR-PS = INT\left(\frac{\sum_{j=1}^{m} AIR-PS_j}{m}\right) \quad \textbf{[Eq.9]}$$

where m is the number of investigated persons.

For non-numeric (linguistic) information, the data must be converted to a numeric value and used in the appropriate DSS engine. In order to convert the information about these factors into numeric values, suitable modules must be used, with each bridge type assigned a numeric value, in order to be able to use it in the DSS engine input data.

Figure 5 shows a bridge file that groups five categories as previously defined. After all the necessary data has been collected from existing bridges, a unique schedule is created that covers all candidates. Statistical analysis is performed to observe the scattered data points, and tables and charts are provided to help decision-makers control their subjectivity. After drawing the appropriate diagrams between the criteria, the bridge type can be statistically defined. This method can be applied to any related project based on the variables gathered from Categories III and IV.

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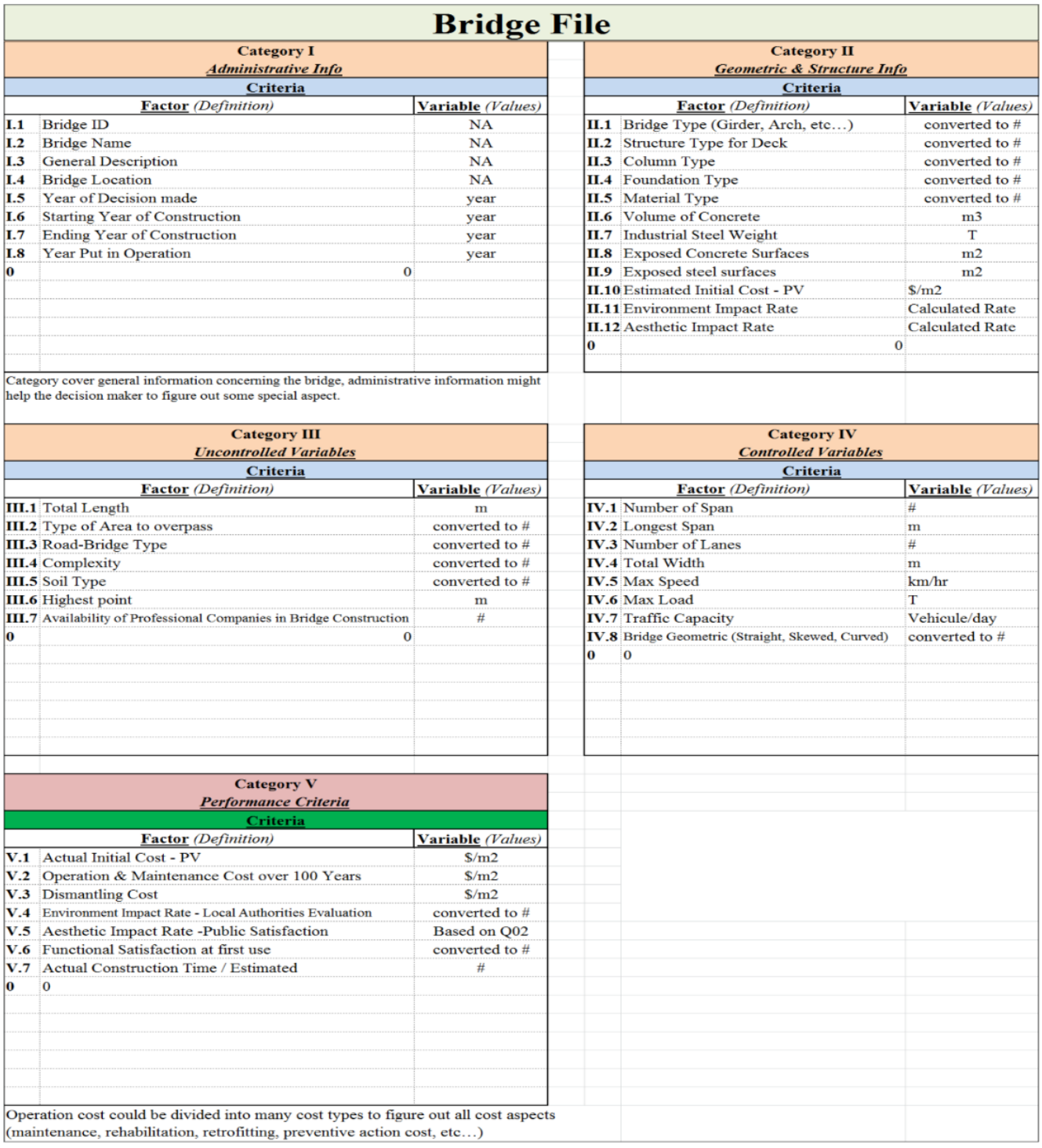

Bridge File

Category I *Administrative Info*

Criteria		
	Factor *(Definition)*	**Variable** *(Values)*
I.1	Bridge ID	NA
I.2	Bridge Name	NA
I.3	General Description	NA
I.4	Bridge Location	NA
I.5	Year of Decision made	year
I.6	Starting Year of Construction	year
I.7	Ending Year of Construction	year
I.8	Year Put in Operation	year
0	0	

Category cover general information concerning the bridge, administrative information might help the decision maker to figure out some special aspect.

Category II *Geometric & Structure Info*

Criteria		
	Factor *(Definition)*	**Variable** *(Values)*
II.1	Bridge Type (Girder, Arch, etc…)	converted to #
II.2	Structure Type for Deck	converted to #
II.3	Column Type	converted to #
II.4	Foundation Type	converted to #
II.5	Material Type	converted to #
II.6	Volume of Concrete	m3
II.7	Industrial Steel Weight	T
II.8	Exposed Concrete Surfaces	m2
II.9	Exposed steel surfaces	m2
II.10	Estimated Initial Cost - PV	$/m2
II.11	Environment Impact Rate	Calculated Rate
II.12	Aesthetic Impact Rate	Calculated Rate
0	0	

Category III *Uncontrolled Variables*

Criteria		
	Factor *(Definition)*	**Variable** *(Values)*
III.1	Total Length	m
III.2	Type of Area to overpass	converted to #
III.3	Road-Bridge Type	converted to #
III.4	Complexity	converted to #
III.5	Soil Type	converted to #
III.6	Highest point	m
III.7	Availability of Professional Companies in Bridge Construction	#
0	0	

Category IV *Controlled Variables*

Criteria		
	Factor *(Definition)*	**Variable** *(Values)*
IV.1	Number of Span	#
IV.2	Longest Span	m
IV.3	Number of Lanes	#
IV.4	Total Width	m
IV.5	Max Speed	km/hr
IV.6	Max Load	T
IV.7	Traffic Capacity	Vehicule/day
IV.8	Bridge Geometric (Straight, Skewed, Curved)	converted to #
0	0	

Category V *Performance Criteria*

Criteria		
	Factor *(Definition)*	**Variable** *(Values)*
V.1	Actual Initial Cost - PV	$/m2
V.2	Operation & Maintenance Cost over 100 Years	$/m2
V.3	Dismantling Cost	$/m2
V.4	Environment Impact Rate - Local Authorities Evaluation	converted to #
V.5	Aesthetic Impact Rate -Public Satisfaction	Based on Q02
V.6	Functional Satisfaction at first use	converted to #
V.7	Actual Construction Time / Estimated	#
0	0	

Operation cost could be divided into many cost types to figure out all cost aspects (maintenance, rehabilitation, retrofitting, preventive action cost, etc…)

Figure 5. Bridge ID file

Figure 6 shows the relationship between Total Bridge Length (TL), (TA), Road Bridge Type (RBT), Soil Type (ST), and Highest Point (HP), as based on the selected Bridge Type (BT). It should be noted that the values shown in Figure 6 are retrieved from the diagrams already clarified and previously created. In addition, the values shown are to be understood as guide values without any specific meaning.

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For the actual case study		Importance Factor	II.1 - BT				
			Rigid Frame Bridges	Beam Bridges / Girder Bridges	Arch Bridges / Through Arch Bridges	Truss Bridges	Cantilever Bridges
Chosen as per actual case study			10	20	30	40	50
III.1 - TL - Total Length - 310 m		5	0	7.5	0	0	0
III.2 - TA - Type of Area to overpass - 5		5	0	7.5	3.8	0	0
III.3 - RBT - Road Bridge Type - 1		5	3.8	30.2	3.8	0	0
III.5 - ST - Soil Types - 1		5	3.8	24.5	0	0	0
III.6 - HP - Highest point - 90 m		5	0	1.9	0	0	0
	Raw Score		38	358	38	0	0
	Percentage		8.8	82.5	8.76	0	0

Figure 6. Statistical definition for a bridge type

4.2 Information Modeling Tools with Conceptual Design Procedures

The benefits of using BrIM tools are extended to the bridge lifecycle. The purpose of using such software in the conceptual design phase is to reduce possible conflicts in the detailed analysis and to retrieve the required quantities for the DSS engine, which can be used for further 3D visualization options. The interoperability between these modules is semi-automatic because they come from the same product family. Adapting the software mentioned leads to the maximum benefit that can be applied from the current version. However, these unpleasant shortcomings are not major problems that can affect the use of the BrIM, since their primary function is to exchange data.

4.3 DSS Engine – Procedures and Analysis

Applying an artificial intelligence (AI) approach would have a huge impact on the goals of this research, firstly by reducing subjectivity in decision-making and, secondly, by providing a systematic methodology that offers the optimal solution for each related problem within a project. Also, since this research examines a system that behaves rationally like a human, it is important to select subsets of artificial intelligence (AI); ANN can be used. The advantage of the selected software is the Simulink option, a graphic programming environment for modeling, simulating and analyzing dynamic multi-domain systems. Its primary user interface is a graphical block diagram tool and a customizable set of block libraries to make it easier to work with. On the other hand, normalization, training, validation and test sets are started automatically to provide the best solution taking into account all ANN concerns, such as avoiding overfitting and the cross-validation process. The learning process for the ANN is divided into two steps: first arrangement and final arrangement. As defined, the factors from Category I are not to be used in the direct calculation. The factors from Categories III and IV are used for the initial design of the learning process, in order to provide possible alternatives that define the factors

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from Category II according to the location characteristics of the new bridge project. Then, based on the factors from Categories II, III and IV, a final arrangement is made to predict the performance criteria for the new bridge to be built. The first agreement aims to provide the potential alternatives for a new bridge project defined by its characteristics (based on the location constraints). These characteristics will assess some of the variables related to the factors from Categories III and IV.

Figure 7 shows the flow diagram of this process. The data from Categories III and IV is used as input neurons, and the data from Category II is selected as target values (as output for the training process). After the training, the validation and the test, the trained ANN is used to define the possible alternatives, and after expert judgment and suggestions, the bridge types with their components (Bridge Type (BT), (CT), (DT), (FT) are defined and they are included in Category II. Then, the variables of Categories II, III and IV are defined for the new proposed bridge, which is implemented in the BrIM tool environment. From the first arrangement, the new project features are implemented for various alternatives in the BrIM environment.

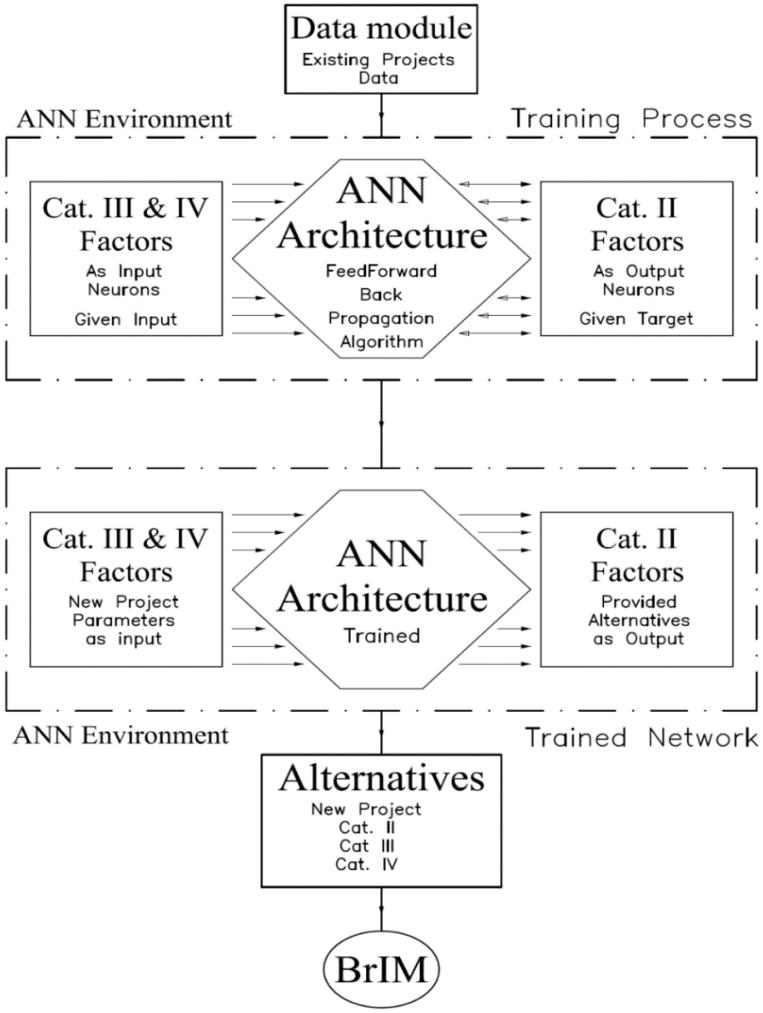

Figure 7. First arrangement flow chart

The respective flowchart is shown in Figure 8; the data are implemented into the Revit module, which geometrically interprets the elements based on an architectural perception. Then, the model is sent to Robot for preliminary design verification; the data exchange between these two modules (Revit and Robot) is based on the coordination between the architecture and structural disciplines. After the architecture and structure constraints have been compared, the final data is provided for each

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alternative and then transferred to the final arrangement process. Using the same procedure as in the first arrangement, an ANN must be trained based on the established data module shown in Figure 9.

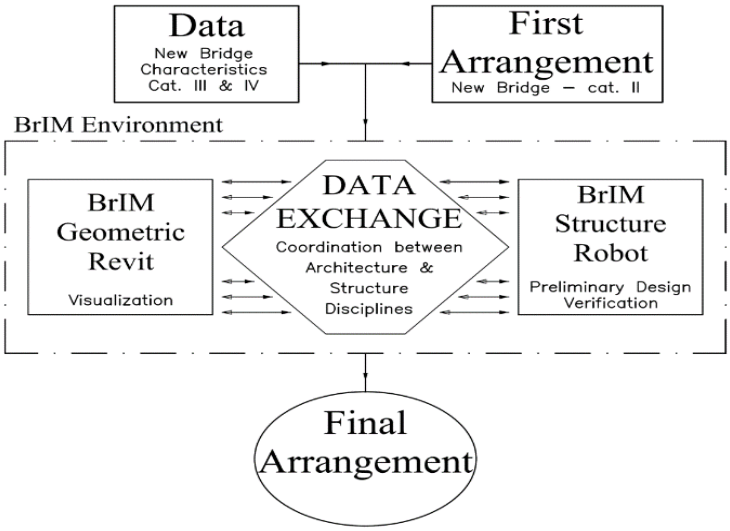

Figure 8. BrIM data interchange flow chart

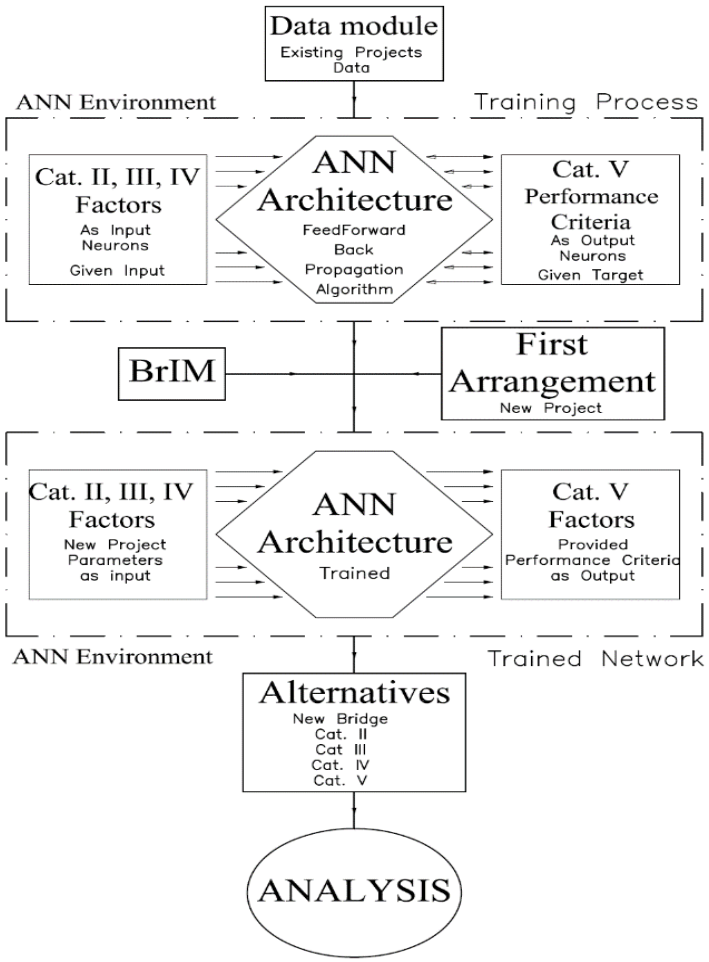

Figure 9. Final arrangement flow chart

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For the training of the ANN, data from the existing projects are used, with the variables of Categories II, III and IV as input neurons, and the variables of Category V as output neurons (target values). The trained ANN is used to define the performance criteria for each alternative, with the input neurons being those of the variables from Categories II, III and IV of a new bridge project. The analysis of the results is then performed by: (1) Testing the ANN reliability and verifying many parameters from the ANN tools. The R values for the overall response should be greater than 0.95 to be in the acceptable ranges in which highlighting the influence of the parameters on the results that the ANN delivers after its training; (2) Examining the uncertainty of the results (outputs) using Sensitivity Analysis (SA) techniques, which identify the impact of each factor on each performance criterion through the final assembly network. Taking into account that the ANN is a non-linear process in terms of the output values, it is logical that the curves of the sensitivity analysis can take any shape; (3) Definition of the realistic level of results with a process of comparison between results of a proposed new method and results of an existing method that produces the same type of results, in order to assess how reliable the results provided are. All data and results from the modules and networks are collected and presented, but a final decision is still pending. For each performance criterion, the optimized value can be related to another alternative. For example, if the decision-maker is more interested in the performance criteria D1, he or she will suggest an alternative that provides an optimized value. The different values of D1-i (i = 1 to n) and so on. For this reason, a Quality Function Deployment (QFD) is proposed, in order to make an unambiguous final decision based on the importance factors (IFj) assigned to the various performance criteria and the optimized raw score value (RSi) (Eq. 11). It is important to mention that the values used in the proposed Quality Function Deployment (QFD) should be normalized (NDj-i) with a linear interpolation between 1 and 10, considering that 10 is assigned to the best scenario (and not the highest value), based on the equation (Eq. 10):

$$ND_{j-i} = \left[9 * \frac{D_{j-i} - Min(D_{j-i})}{Max(D_{j-i}) - Min(D_{j-i})} + 1 \right] \quad \textbf{[Eq.10]}$$

where:

	j	Performance criteria indices
	m	Total number of performance criteria
	i	Alternative indices
	n	Total number of alternatives
	D_{j-i}	Performance criteria value
	N	Normalization symbol

Then, the raw score values are calculated based on Equation 11:

$$RS_i = \left[\sum_{j=1}^{m} IF_j * ND_{j-i} \right] \quad \textbf{[Eq.11]}$$

where:

	IF	Importance Factor
	ND	Normalized performance criteria value
	j	Performance criteria indices
	m	Total number of performance criteria
	i	Alternative indices

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5. CASE STUDY: LEBANON

5.1 Introduction

In order to validate the results based on the previously discussed methodology, a case study was undertaken to verify the proposed DSS method using a bridge project designed and planned in Lebanon.

It should be noted that Lebanon is considered an exceptional case in terms of design, tendering and other concerns that directly and indirectly affect the results and behavior of Artificial Intelligence (AI) in the analysis. Hence, it is expected that a wide variety and heterogeneity of data with differing opinions is obtained from among experts working in the Middle East.

In addition, the application of the DSS is applied to identify all kinds of inaccuracies as much as possible and to validate the proposed DSS. Congestion and traffic problems are the main reasons that have led to the construction of a new bridge to provide a direct connection between two areas and to relieve the traffic on the coastal road.

The global information regarding the new bridge to be built is:

(1) Total Length, TL = 310 m;

(2) Type of area to be crossed, TA = Valley;

(3) Road Bridge Type, RBT = non-highway;

(4) Soil Type, ST = rock;

(5) Highest Point, HP = 90m;

(6) Maximum Speed, MS = 50 km / h;

(7) Maximum Load, ML = 50T; (8) Traffic Capacity, TRC = 6,000 vehicles/day.

5.2 Data Collection and Analysis

A new data module was created and defined for the DSS. In order to be consistent in the analysis, social and economic constraints were also taken into account with the Q01 questionnaire (Figure 10). In order to define the criteria to be taken into account, 49 experts were interviewed and the results were summarized in a time schedule. The report was analyzed and the factors with the highest values were taken into account in the data module to be assigned for Categories III, IV & V. After defining the factors to be considered, an additional study of the project area was carried out, in order to determine the appropriate variables for the selected factors. Information for 53 existing bridges was collected and saved in a corresponding time schedule. Some of the data were collected directly; others were derived from statistical analyses and the application of defined procedures.

Questionnaire Q02 (see Figure 11) was used for data collection and later formulated to provide the previously discussed “Aesthetic Effect Rate - Public Satisfaction (AIR-PS)”. In the statistical studies, the traffic was calculated for each existing bridge and saved in questionnaire Q02; later, information was transferred to the corresponding factor in Category IV (traffic capacity).

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Questionnaire Q01

Subject:	Criteria Affecting the Bridge Design and Performance	#
Addressed To:	Private & Public Agencies and Companies	

Date:	***Type:*** *(2)*
Company name:	*Gov./CM/Cons.*
Participant name /Function:	

Q01-A *(Soft Factors)*

A new Bridge type is going to be selected; in your opinion, what are the Criteria that might define the bridge performance.
Rate each provided Criteria from 1 to 10 respecting its importance level
(Hint: refer to the back-sheet for some proposed criterias)

Criteria	Rate	Criteria	Rate	Criteria	Rate

Q01-B *(Hard Factors)*

A new Bridge type is going to be selected; in your opinion, what are the factors that have influence on the bridge performance Criteria.
Rate each provided factor from 1 to 10 respecting its influence level.
(Hint: refer to the back-sheet for some proposed factors)

Factors	Rate	Factors	Rate	Factors	Rate

NB:
1. It is preferable to participate more than one participant (decision-maker, Senior Engineer) from one Company/Agency
2. Gov.: Government Agency; CM: Construction Management or Main Contractor; Cons.: Consultant Agency
3. Use another sheet if more space is needed.

Figure 10. Questionnaire Q01

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Questionnaire Q02

Subject:	Aesthetic Impact Rate - Public Satisfaction	#
Addressed To:	Public & Users	
Date:	5-Dec-16	***AIR-PS***
Student's Group #	Gr. 02	**7**
Bridge Investigated: Bridge #	ID 10	

Traffic Monitoring **(Number of Vehicules)**

Week 1	**Mo**	13450	**Fr**	14055	**Week 2**	**Mo**	11800	**Fr**	13240	**Week 3**	**Mo**	14560	**Fr**	14650	**Results - Daily Av. Traffic**						
	Tu	12450	**Sat**	7500		**Tu**	15200	**Sat**	9150		**Tu**	13150	**Sat**	8670							
	We	11750	**Sun**	13250		**We**	14250	**Sun**	13750		**We**	13200	**Sun**	14750	**12575**						
	Th	11450				**Th**	12250				**Th**	11540									

Aesthetic Criteria:	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**
Proportion and geometry	10	8	9	10	4	8	8	10	8	10	8	10	8	10	8	9	8	8	8	6
Environmental	8	10	8	8	8	9	8	10	9	10	9	7	8	8	10	9	9	8	7	9
Structural harmony	9	10	6	10	9	8	8	9	8	10	8	10	9	8	9	10	6	8	9	6
Focus of attention	8	9	9	6	9	10	9	8	9	9	8	8	8	10	9	7	9	9	8	7
Weathering and surface finish	8	9	10	7	8	6	10	9	8	7	8	9	5	8	6	10	10	9	9	9
	8		7		6		8		8		7		7		7		7		6	

Aesthetic Criteria:	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**	**I**	**V**
Proportion and geometry	8	8	10	8	10	8	9	8	10	8	9	6	8	8	9	10	9	10	8	9
Environmental	8	7	8	10	9	10	7	8	8	9	8	10	6	8	8	8	8	8	9	8
Structural harmony	9	6	8	10	9	10	8	8	10	9	8	8	8	4	9	7	8	8	7	10
Focus of attention	8	8	8	10	9	9	9	8	9	10	8	10	8	9	8	8	9	10	6	7
Weathering and surface finish	10	9	10	8	8	8	8	8	8	8	8	10	8	8	8	7	8	9	8	8
	6		8		8		6		8		7		6		7		7		6	

Notes & Comments

Aesthetic Criteria

I: Importance factor related to the selected criteria based on the participant opinion
1: low importance; 10: highest importance rate

V: Rated Criteria of the the participant. 1: low acceptable rate; 10: high acceptable rate

Figure 11. Questionnaire Q02 – Gr.02 – Bridge ID10

Public opinions were stored in questionnaire Q02 to obtain opinions on aesthetic satisfaction based on the five characteristics as noted in the previous sections. The performance criteria for the bridge aesthetics were evaluated using the [Eq. 8] and [Eq. 9]. In addition, two further variables,

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Environmental Impact Rate (EIR) and (b) Aesthetic Impact Rate (AIR), from Category II were also formulated and evaluated according to the equations [Eq. 6] and [Eq. 7]. The existing Bridge (# 010) required the following information to evaluate its Environmental Impact Rate (EIR) and (b) Aesthetic Impact Rate (AIR) variables:

Total Bridge Area	11,832	**TBA (m^2)**
Affected Natural Areas	3,550	**ANA (m^2)**
Total Concrete Volume	12,450	**CV (m^3)**
Total Industrial Steel Weight	0	**ISW (T)**

Using equations [Eq. 6; 6a; 6b; 6c], the Environmental Impact Rate (EIR) variable was obtained using the associated quantities that were collected during the examinations of the existing bridge (# 010). After establishing the data module, it was important to analyze its content for clarity and consistency and to find out whether it is homogeneous, heterogeneous, asymmetrical and realistic.

The goal of the first step is to define the alternatives in terms of Category II (i.e. Bridge Type (BT), (DT) and (CT)). On the basis of the criteria mentioned in Categories III and IV, a statistical analysis was carried out to link the factors (ANN nodes/weights and elements) from Categories III and IV to Category II.

Further, the statistical relationship between the Bridge Types (BT) with their Total Lengths (TL), using the data plan, showed that the bridge number of a particular bridge type is distributed according to its total length. In addition, similar relationships were established between all factors of Categories III and IV with different bridge types and linked to every other category II factor that defines the bridge components (Bridge Type (BT), (DT), (CT), (FT), (MT)). The relationship between the bridge types with “type of area to be crossed”, “road bridge type (RBT)”, “soil type (ST)” and “highest point (HP)” was examined.

With reference to Figure 6 and based on the various statistical analyzes of the associated graphical representations, the alternatives for a new type of bridge were defined and presented in the Quality Function Deployment (QFD) system.

For the Total Length (TL) input data (row), the assigned value "7.5" was obtained by taking into account a section of the total length of between 300 and 400 m; this provided a figure of 7.5% for the given bridge type. In the same way, the values "7.5" and "3.8" regarded as statistical values as per the Type of Area to Overpass (TA) / Bridge Type (BT) diagram, the values "3.8", "30.2" and "3.8" as per the Road Bridge Type (RBT) / Bridge Type (BT) diagram, the values "3.8" and "24.5" as per the Soil Type (ST) / Bridge Type (BT) diagram and, finally, the value "1.9" as per the Highest Point (HP) / Bridge Type (BT) diagram.

It should be noted that the raw score for each bridge type candidate must be calculated based on the importance factor assigned to each influencing factor (TL, TA, RBT, ST, HP) using the following equation:

$$\text{Raw Score for } BT_{\mathbf{I}} = \Sigma[\text{Importance factor} * Q_I]_{\mathbf{J}} \quad \textbf{[Eq.12]}$$

where:

J = TL, TA, RBT, ST, HP (Influence factors considered)
I = 10, 20, 30, 40, 50 (Bridge Types)

Then, a percentage is calculated and presented in the last row.

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5.3 DSS Engine and Brim

As a first arrangement and based on the retrieved data, ANN was trained according to Table 1, which represents the input data for the ANN, and Table 2, which represents the target (output) values.

For the new case project, the relevant data shown in Table 3 were used in the trained ANN to obtain the predicted results, as shown in Table 4. Based on these results, various alternatives are suggested in Table 5, which - in the final arrangement - are possible solutions.

When proposing alternatives, technical judgment is emphasized as the technical aspects (geometry and structure) need to be checked, especially during the BrIM implementation phase. The BrIM implementation was done based on the suggested alternatives, and five perspectives were created using the Autodesk Revit software, and then transferred to the robot module for preliminary design reviews.

Following many interpretations and work on the corresponding software, the complete data for the variables of Category II were determined; these are shown in Table 6.

Table 1 – Input data for the first arrangement (for 6 of 53 existing bridge cases)

		Input		001	002	003	004	005	006
III.1	L	Total Length	m	140	310	215	35	35	32
III.2	TA	Type of Area to overpass	converted to #	20	20	10	10	10	10
III.3	RBT	Road-Bridge Type	converted to #	10	20	10	10	10	10
III.4	Com	Complexity	converted to #	10	10	30	10	10	10
III.5	TS	Soil Type	converted to #	10	30	10	20	20	20
III.6	HP	Highest point	m	150	30	7	5.5	5.5	6
III.7	AP	Availability of Professional Companies in Bridge Construction	#	5	5	3	3	3	3
IV.1	SN	Number of Span	#	14	7	9	2	2	2
IV.2	LS	Longest Span	m	140	60	25	18	18	18
IV.3	NL	Number of Lanes	#	4	6	2	2	2	2
IV.4	TW	Total Width	m	26	30	12	12	10	10
IV.5	MS	Max Speed	km/hr	80	100	50	40	40	40
IV.6	ML	Max Load	T	60	100	60	30	30	30
IV.7	TRC	Traffic Capacity	Vehicule/day	24352	21572	7588	4792	2014	1556
IV.8	BG	Bridge Geometric (Straight, Skewed, Curved)	converted to #	10	10	10	20	20	10

Table 2 – Target Data for the first arrangement (for 6 of 53 existing bridge cases)

		Target		001	002	003	004	005	006
II.1	BT	Bridge Type (Girder, Arch, etc…)	converted to #	30	20	20	20	20	20
II.2	DT	Structure Type for Deck	converted to #	10	40	10	10	10	10
II.3	CT	Column Type	converted to #	0	20	10	30	20	20
II.4	FT	Foundation Type	converted to #	10	10	10	10	10	10
II.5	MT	Material Type	converted to #	10	10	10	10	10	10
II.6	CV	Volume of Concrete	m^3	2562	1225	3125	625	560	525
II.7	ISW	Industrial Steel Weight	T	0	0	0	0	0	0
II.8	CS	Exposed Concrete Surfaces	m^2	4320	21550	3325	556	425	380
II.9	SS	Exposed steel surfaces	m^2	0	0	0	0	0	0
II.10	EIC	**Estimated Initial Cost - PV**	**$/$m^2$**	**850**	**1150**	**1250**	**950**	**850**	**850**
II.11	EIR	Environment Impact Rate	Calculated Rate	9	6	16	17	17	17
II.12	AIR	Aesthetic Satisfaction Rate	Calculated Rate	8	7	5	4	4	4

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Table 3 – Input data for new case project – first arrangement

NEW INPUT - Case Study Data				CS 1
III.1	L	Total Length	m	310
III.2	TA	Type of Area to overpass	converted to #	20
III.3	RBT	Road-Bridge Type	converted to #	10
III.4	Com	Complexity	converted to #	10
III.5	TS	Soil Type	converted to #	10
III.6	HP	Highest point	m	90
III.7	AP	Availability of Professional Companies in Bridge Construction	#	5
IV.1	SN	Number of Span	#	10
IV.2	LS	Longest Span	m	30
IV.3	NL	Number of Lanes	#	2
IV.4	TW	Total Width	m	9
IV.5	MS	Max Speed	km/hr	50
IV.6	ML	Max Load	T	50
IV.7	TRC	Traffic Capacity	Vehicule/day	6000
IV.8	BG	Bridge Geometric (Straight, Skewed, Curved)	converted to #	10

Table 4 – Predicted outputs for new case project – first arrangement

Output - From Trained ANN Matlab				CS 1	Equivalents	
II.1	BT	Bridge Type (Girder, Arch, etc…)	converted to #	29.2875	20-30	
II.2	DT	Structure Type for Deck	converted to #	11.25	10	
II.3	CT	Column Type	converted to #	26.6361	20-30	
II.4	FT	Foundation Type	converted to #		10	Selected without analysis - Obviously
II.5	MT	Material Type	converted to #	10.008	10	Obviously
II.6	CV	Volume of Concrete	m^3	Calculated based on the proposed Alternatives & BrIM		
II.7	ISW	Industrial Steel Weight	T			
II.8	CS	Exposed Concrete Surfaces	m^2			
II.9	SS	Exposed steel surfaces	m^2			
II.10	EIC	Estimated Initial Cost - PV	$/m^2	883	885	Value to be verified for each proposed alternative
II.11	EIR	Environment Impact Rate	Calculated Rate	Values to be calculated based on EIR-Cat II &		
II.12	AIR	Aesthetic Satisfaction Rate	Calculated Rate	Aesthetic Satisfaction Rate - AIR - Cat II		

Table 5. Proposed Alternatives for new case project – first arrangement

Input Data for Final Arrangement				Alt1	Alt2	Alt3	Alt4	Alt5
II.1	BT	Bridge Type (Girder, Arch, et	converted to #	30	30	20	20	20
II.2	DT	Structure Type for Deck	converted to #	10	30	10	30	50
II.3	CT	Column Type	converted to #	**10**	**10**	**30**	**30**	**20**
II.4	FT	Foundation Type	converted to #	10	10	10	10	10
II.5	MT	Material Type	converted to #	10	10	10	10	10
II.10	EIC	Estimated Initial Cost - PV	$/m^2	885	885	885	885	885

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Table 6. Proposed Alternatives for new case project – Cat. II variables following BrIM implementation

Input Data for Final Arrangement				Alt1	Alt2	Alt3	Alt4	Alt5
II.1	BT	Bridge Type (Girder, Arch, et	converted to #	30	30	20	20	20
II.2	DT	Structure Type for Deck	converted to #	10	30	10	30	50
II.3	CT	Column Type	converted to #	**10**	**10**	**30**	**30**	**20**
II.4	FT	Foundation Type	converted to #	10	10	10	10	10
II.5	MT	Material Type	converted to #	10	10	10	10	10
II.6	CV	Volume of Concrete	m^3	4350	4300	5250	5500	5150
II.7	ISW	Industrial Steel Weight	T	0	0	0	0	0
II.8	CS	Exposed Concrete Surfaces	m^2	6150	7250	6050	7250	6350
II.9	SS	Exposed steel surfaces	m^2	0	0	0	0	0
II.10	EIC	Estimated Initial Cost - PV	$/m^2$	885	885	885	885	885
II.11	EIR	Environment Impact Rate	Calculated Rate	17	14	18	19	18
II.12	AIR	Aesthetic Satisfaction Rate	Calculated Rate	6	5	6	7	6

The final arrangement is the final step of extracting and analyzing the results. In this phase, to train the corresponding ANN, the variables of Categories II, III and IV from the data module are considered as input data and the variables of Category V as target values (outputs). Tables 7 and 8 summarize some of these variables. After training the ANN, verification was carried out by testing the existing cases and the differences between the target and output values were highlighted. Table 9 shows the input values for new bridge cases (alternatives) to be examined by the trained ANN, in order to extract the performance criteria for the various alternatives. The performance criteria for the various alternatives are shown in Table 10. All necessary verifications, validations and tests were carried out, in order to assign an optimal level of reliability to the trained ANN, without ignoring that the ANN environment could lead to a certain probability of dissatisfaction and uncertainty; this required an additional analysis in relation to the sensitivity analysis and the realistic level.

5.4 Results Analysis

Before a final decision can be made on the basis of a systematic process, an analysis of the results is necessary, in order to understand the previous results with their possible degree of uncertainty. Therefore, for some factors, Sensitivity Analysis (SA) is an essential technique that must be used to highlight the uncertainty, and the realistic level is important to validate the extracted results.

The factors that influenced the decision were examined through interviews with the experts and then they were defined and implemented in the data module and exported to the DSS engine to make the appropriate decision. However, the level of their influence is still unclear, as is the uncertainty inherent in the values assigned to these factors.

To solve this problem, sensitivity analysis is the best tool. To do this, some factors are selected in the final arrangement to assess their impact by assigning different values and monitoring the variations in performance criteria. The selected factors to investigate are: (1) Concrete Volume, (2) Estimated Initial Cost, (3) Environmental Impact Rate, (4) Aesthetic Impact Rate, and (5) availability of professional bridge construction companies; the sensitivity analysis was only carried out for alternatives (1) and (3).

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In the following, the variations of the performance criteria are presented. The fluctuations in the selected performance criteria were recorded as follows: (1) Actual acquisition costs - PV; (2) operating and maintenance costs over 100 years; (3) dismantling costs; (4) Environmental Impact Rate - assessment by local authorities; (5) Aesthetic Satisfaction Rate - Public Satisfaction; (6) first-time functional satisfaction; and (7) actual / estimated construction time.

Table 7. Input data for the final arrangement

INPUT				001	002	003	004	005	006	.....
II.1	BT	Bridge Type (Girder, Arch, etc…)	converted to #	30	20	20	20	20	20	
II.2	DT	Structure Type for Deck	converted to #	10	40	10	10	10	10	
II.3	CT	Column Type	converted to #	10	30	20	40	30	30	
II.4	FT	Foundation Type	converted to #	10	10	10	10	10	10	
II.5	MT	Material Type	converted to #	10	10	10	10	10	10	
II.6	CV	Volume of Concrete	m^3	2562	1225	3125	625	560	525	
II.7	ISW	Industrial Steel Weight	T	0	0	0	0	0	0	
II.8	CS	Exposed Concrete Surfaces	m^2	4320	21550	3325	556	425	380	
II.9	SS	Exposed steel surfaces	m^2	0	0	0	0	0	0	
II.10	EIC	**Estimated Initial Cost - PV**	**$/m^2**	**850**	**1150**	**1250**	**950**	**850**	**850**	
II.11	EIR	Environment Impact Rate	Calculated Rate	9	6	16	17	17	17	
II.12	AIR	Aesthetic Satisfaction Rate	Calculated Rate	8	7	5	4	4	4	
III.1	L	Total Length	m	140	310	215	35	35	32	
III.2	TA	Type of Area to overpass	converted to #	20	20	10	10	10	10	
III.3	RBT	Road-Bridge Type	converted to #	10	20	10	10	10	10	
III.4	Com	Complexity	converted to #	10	10	30	10	10	10	
III.5	TS	Soil Type	converted to #	10	30	10	20	20	20	
III.6	HP	Highest point	m	150	30	7	5.5	5.5	6	
III.7	AP	Availability of Professional Companies in Bridge Construction	#	5	5	3	3	3	3	
IV.1	SN	Number of Span	#	14	7	9	2	2	2	
IV.2	LS	Longest Span	m	140	60	25	18	18	18	
IV.3	NL	Number of Lanes	#	4	6	2	2	2	2	
IV.4	TW	Total Width	m	26	30	12	12	10	10	
IV.5	MS	Max Speed	km/hr	80	100	50	40	40	40	
IV.6	ML	Max Load	T	60	100	60	30	30	30	
IV.7	TRC	Traffic Capacity	Vehicule/day	24352	21572	7588	4792	2014	1556	
IV.8	BG	Bridge Geometric (Straight, Skewed, Curved)	converted to #	10	10	10	20	20	10	

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Table 8. Target Data for the final arrangement

INPUT				001	002	003	004	005	006	.....
V.1	IC	Actual Initial Cost - PV	$/m^2	1100	1250	1825	1275	1150	1150	
V.2	OC	Operation & Maintenance Cost over 10	$/m^2	600	1000	2000	1850	1950	1850	
V.3	DC	Dismantling Cost	$/m^2	150	400	500	300	350	350	
V.4	EIR-LA	Environment Impact Rate - Local Authorities Evaluation	converted to #	**10**	20	20	30	20	20	
V.5	AIR-PS	Aesthetic Satisfaction Rate - Public Satisfaction	Based on Q02	**5**	3	5	7	7	7	
V.6	FS	Functional Satisfaction at first use	converted to #	**10**	10	20	30	30	30	
V.7	CTM	Actual Construction Time / Estimated	#	2	1.5	2	2	1.75	2	

Table 9. Input data for new case project – final arrangement

Input Data for Final Arrangement				Alt1	Alt2	Alt3	Alt4	Alt5
II.1	BT	Bridge Type (Girder, Arch, etc…)	converted to #	30	30	20	20	20
II.2	DT	Structure Type for Deck	converted to #	10	30	10	30	50
II.3	CT	Column Type	converted to #	**10**	**10**	**30**	**30**	**20**
II.4	FT	Foundation Type	converted to #	10	10	10	10	10
II.5	MT	Material Type	converted to #	10	10	10	10	10
II.6	CV	Volume of Concrete	m^3	4350	4300	5250	5500	5150
II.7	ISW	Industrial Steel Weight	T	0	0	0	0	0
II.8	CS	Exposed Concrete Surfaces	m^2	6150	7250	6050	7250	6350
II.9	SS	Exposed steel surfaces	m^2	0	0	0	0	0
II.10	EIC	**Estimated Initial Cost - PV**	**$/m^2**	885	885	885	885	885
II.11	EIR	Environment Impact Rate	Calculated Rate	17	14	18	19	18
II.12	AIR	Aesthetic Satisfaction Rate	Calculated Rate	6	5	6	7	6
III.1	L	Total Length	m	310	310	310	310	310
III.2	TA	Type of Area to overpass	converted to #	20	20	20	20	20
III.3	RBT	Road-Bridge Type	converted to #	10	10	10	10	10
III.4	Com	Complexity	converted to #	10	10	10	10	10
III.5	TS	Soil Type	converted to #	10	10	10	10	10
III.6	HP	Highest point	m	90	90	90	90	90
III.7	AP	Availability of Professional Companies in Bridge Construction	#	5	5	5	5	5
IV.1	SN	Number of Span	#	13	13	8	8	8
IV.2	LS	Longest Span	m	20	20	60	60	60
IV.3	NL	Number of Lanes	#	2	2	2	2	2
IV.4	TW	Total Width	m	9	9	9	9	9
IV.5	MS	Max Speed	km/hr	50	50	50	50	50
IV.6	ML	Max Load	T	50	50	50	50	50
IV.7	TRC	Traffic Capacity	Vehicule/day	6000	6000	6000	6000	6000
IV.8	BG	Bridge Geometric (Straight, Skewed, Curved)	converted to #	10	10	10	10	10

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Table 10. Predicted outputs (performance criteria) for new case project case - final arrangement

Output (performance criteria) from Trained ANN Matlab				Alt1	Alt2	Alt3	Alt4	Alt5
V.1	IC	Actual Initial Cost - PV	$/m^2	991	986	1157	1194	1131
V.2	OC	Operation & Maintenance Cost ov	$/m^2	3947	4932	3655	4728	5527
V.3	DC	Dismantling Cost	$/m^2	751	708	533	306	178
V.4	EIR-LA	Environment Impact Rate - Local Authorities Evaluation	converted to #	13	14	16	16	23
V.5	AIR-PS	Aesthetic Satisfaction Rate - Public Satisfaction	Based on Q02	4	6	3	3	4
V.6	FS	Functional Satisfaction at first use	converted to #	15	16	44	45	43
V.7	CTM	Actual Construction Time / Estim	#	1.27	1.35	1.65	1.34	1.31

Referring to Figure 12, a sensitivity analysis is performed on the initial cost prediction (performance criteria) by applying different values for the listed factors. For example, the projected initial cost increases as the estimated initial cost increases. With regard to the environment, it is clear that environmental protection and the forecast acquisition costs will also increase. Other factors, such as Concrete Volume, have no significant effect as their curves are either horizontal or parabolic.

Alt1 / Initial Cost					
Total Volume	1000	2000	4350	8000	12000
Initial Cost	1468	1497	1505	1502	1571
Estimated Cost	500	650	885	1000	1200
Initial Cost	1040	1209	1505	1667	1975
Availability of Profe	1	3	5	8	10
Initial Cost	1680	1548	1505	1835	2125
EIR	5	10	17	20	30
Initial Cost	1856	1694	1505	1446	1356
AIR	1	3	6	8	10
Initial Cost	1939	1565	1505	1619	1730
Different values considered for Sensitivity Analysis					

Alt1 / Initial Cost					
Total Volume	23%	46%	100%	184%	276%
Initial Cost	98%	99%	100%	100%	104%
Estimated Cost	56%	73%	100%	113%	136%
Initial Cost	69%	80%	100%	111%	131%
Availability of Profe	20%	60%	100%	160%	200%
Initial Cost	112%	103%	100%	122%	141%
EIR	29%	59%	100%	118%	176%
Initial Cost	123%	113%	100%	96%	90%
AIR	17%	50%	100%	133%	167%
Initial Cost	129%	104%	100%	108%	115%
The Different percentages considered for Sensitivity Analysis					

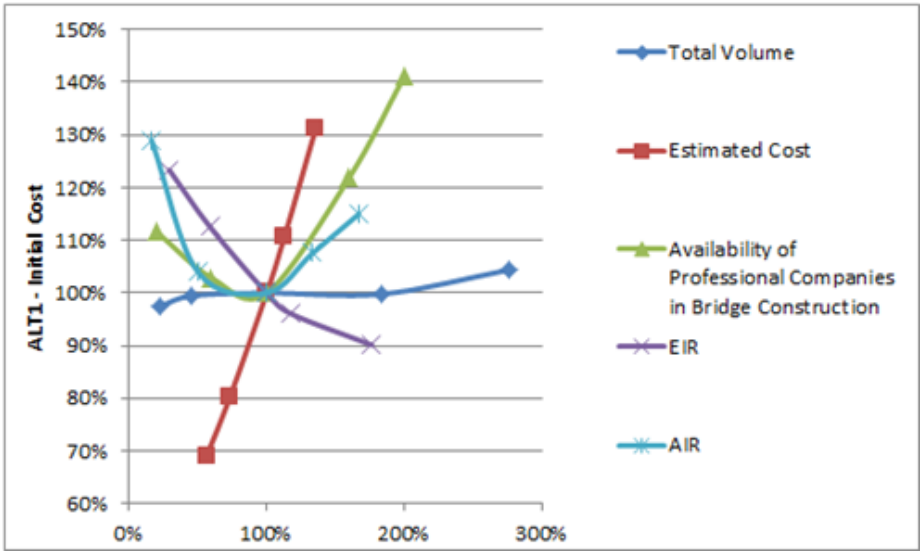

Figure 12. Sensitivity analysis for the predicted initial cost criteria

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Many traditional methods may exist that provide a graphical solution to selecting an appropriate type of bridge or bridge deck, based on one or more factors. In order to assess the realistic level of the results of the methods mentioned, a comparison of the results with those of the actual DSS is carried out. What is proposed is based on the information already implemented in the data module.

It should be noted that the predicted initial cost (IC) can be compared to the estimated initial cost (EIC) by applying the following steps:

(1) calculating the mean and standard deviation for the EIC / IC ratio of the existing bridges; and
(2) comparing the new bridge ratio to the mean within a 2σ (2 times standard deviation) interval.

The same procedure is followed and compared to any predicted performance criteria for a new bridge project with some ratio. As shown in Table 11, the suggested interval for two standard deviations, some values were found to be outside the suggested interval. Another interval like the 6*sigma (6σ) adopted could be used, but the main problem is that, as it concerns the conceptual design phase, a miscalculation of up to 50% could be acceptable, as most of the values in Table 11 are within these limits.

Table 11. Realistic level

Level of Realistic		Existing Cases		Extremes / 2σ						
factor	Ratio	Mean	St.Dev.	Min	Max	Alt1	Alt2	Alt3	Alt4	Alt5
IC	IC / EIC	1.348	0.138	1.210	1.486	1.120	1.114	1.307	1.349	1.278
OC	OC / IC	1.763	0.450	1.312	2.213	3.983	5.002	3.159	3.960	4.887
DC	DC / IC	0.262	0.078	0.183	0.340	0.758	0.718	0.461	0.256	0.157
EIR-LA	EIR-LA / EIR	1.657	1.431	0.226	3.089	0.765	0.824	0.762	0.727	1.095
AIR-PS	AIR-PS / AIR	1.053	0.533	0.520	1.586	0.667	1.200	0.500	0.429	0.667
FS	FS / BT	1.239	0.535	0.704	1.773	0.500	0.800	2.200	2.250	2.150
CTM	CTM / BT	0.084	0.026	0.058	0.111	0.042	0.068	0.083	0.067	0.066

5.5 Final Decision

After the analysis has been completed, an obvious final step in the process is required to define a definite final decision. For this purpose, a Quality Function Deployment (QFD) system using the values noted in Table 10 must be considered with an importance factor for each criterion.

The latter could either be assigned by the decision-maker himself on the basis of some constraints or by reference to the priority among the performance criteria defined on the basis of the expert opinions (values related to subjectivity).

The importance factor for each performance criterion is selected within the interval {1, 2, 3, 4, 5, 6, 7} (1 low importance, 7 high importance).

Table 12 calculates the raw score by applying [Eq.6] for the normalization process and [Eq.7] for the raw score values and, based on these values, an appropriate final decision (alternative) is selected.

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Table 12. Factors and values considered for sensitivity analysis

Normalized performance Criteria				Alt1	Alt2	Alt3	Alt4	Alt5
V.1	IC	Actual Initial Cost - PV	7	8	9	2	1	3
V.2	OC	Operation & Maintenance Cost over 100 Years	6	7	3	9	4	1
V.3	DC	Dismantling Cost	5	1	1	4	7	9
V.4	EIR-LA	Environment Impact Rate - Local Authorities Evaluation	4	9	8	6	6	1
V.5	AIR-PS	Aesthetic Satisfaction Rate - Public Satisfaction	2	3	9	1	1	3
V.6	FS	Functional Satisfaction at first use	1	9	8	1	1	1
V.7	CTM	Actual Construction Time / Estimated	3	9	7	1	7	8
		Raw Score		181	165	118	114	107

6. CONCLUSION

This paper aimed to provide a methodology for analyzing subjectivity based on the indispensable expert opinion by providing some tools to support and, if necessary, defend your decision and link your decision to appropriate performance criteria as well as any potential alternatives to be ordered based on expert subjectivities. In this work, a pragmatic method for bridge type selection in the conceptual design phase was developed. It was aimed at: (1) reducing, controlling and emphasizing subjectivity in decision-making, and turning it into objectivity; (2) providing a clear methodology for categorizing and ranking the potential alternatives; (3) taking due account of the beneficial factors proposed by the experts; and (4) providing a systematic methodology based on data from existing projects and expert opinions. There is always bias, because the analysis is made on the basis of different opinions, but the decision-maker has to identify the principles, in order to judge the alternatives.

With regard to the DSS components, it should be noted that the data module is built using a systematic methodology based on expert opinions. Some of the advantages of the three DSS components are: (1) they provide arguments for the subjectivity of the decision maker; (2) they offer flexible and clear steps; and (3) they help accommodate any subjectivity that could be carried forward during the design process. In addition, the data analysis offers the decision-maker the possibility to recognize the degree of uniformity of the data collected. As a result, the decision-maker can see the homogeneity, heterogeneity and asymmetry of the data. Great attention is paid to the data components by disclosing all data processes and giving the decision-maker the flexibility to adapt the data module structure within a systematic methodology to the new case constraints. The properties of the ANN environment, such as the training processes, the number of neurons to be selected within the hidden layer, the checking of the relationship between the number of input neurons and the training cases under consideration, are all regarded as tasks of precision.

A considerable number of studies found in the literature have been checked for their correct work with the ANN, in particular the subject field, data types and the number of cases considered for training. Although a comprehensive analysis was performed using the ANN environment, the final verification of accuracy was due to two factors: (1) training, validation and testing processes; and (2) the level of realistic results with the aim of generalizing the errors. In fact, any technical data analysis is fraught with variability, and it is evident that the compatibility and accuracy of the results will not be 100% achieved; therefore, two aspects must be considered: 1) working in the conceptual design phase means that errors with an accuracy of up to 50% can be acceptable; and 2) the errors and accuracy are well highlighted, and any additional modifications made in the first few steps of the methodology can lead to some improvement. For BrIM tools, their roles are defined by the following objectives: (1) providing the required quantities and specifications; (2) visualizing the alternatives, in order to check how

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realistic the proposed alternatives are; and (3) minimizing as much as possible the modifications and adjustments that may occur during the detailed design phases. The sensitivity analysis, which was carried out at the end of this investigation, gives the decision maker a great deal of leeway in order to evaluate and evaluate well every possible decision that could be made and to identify the possible areas of error.

The notable contributions of the present research are characterized by the following: (1) the final decision is based on many factors that are defined according to the individuality of the respective site and proposed and approved by the experts who provided valuable tools that to one the appropriate decision; This task was solved in a special and critical approach on the basis of the collected data and corresponding questionnaires, in order to determine the influence of the different expert opinions in the region under study; (2) the subjectivity of decision-makers is clearly highlighted and controlled, resulting in a transparency of subjectivity arranged so that it can be compared with other opinions; where the sensitivity analysis and flexibility of the DSS result in maximum control of subjectivity; (3) the different alternatives are ranked on the basis of the importance of the performance criteria that are used to clarify the importance of each alternative; the importance of the performance criteria could differ between one decision maker and another, and this problem gives value to the DSS and can provide a way to analyze the data and provide alternatives based on different viewpoints; (4) the use of BrIM techniques is introduced in the conceptual design phase in a way that maximizes utility; this part consists of determining the life cycle costs resulting from different opinions; (5) the flexibility of the DSS mentioned enables the easy implementation of suitable models from other studies so that this DSS can be applied also to other locations by adopting the available data and technologies. Therefore, the means of DSS flexibility are presented and highlighted.

The manner in which the required data is collected has a great influence on the realism and objectivity of the results. In accordance with expert opinions, important factors are highlighted; therefore, other decision makers may agree with the results and they may be convinced by the analysis. Site characteristics has also taken into account the selected existing similar projects for the engine learning processes. The method used to analyze and manipulate this data affects the determination of its accuracy and its validity for use in the DSS. To this end, among many important concerns of this research, one of the most important is to empower the decision-maker to defend his decision, to fight for it and to convince others of his decision, which is based on a systematic methodology.

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Prevalence of Frailty in Rural Areas of Lebanon

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Keywords

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Lebanon

Abstract

This study aims to identify the prevalence of the frailty syndrome and its association with demographic, economic, health, functional, nutritional, psychological and cognitive variables in rural areas of Lebanon. For this research, a cross-sectional study was conducted among 340 older people, aged 65 years and over, with an average age of 76.3 years. The relationships between stages of frailty and the variables of interest were made using the Pearson correlation and the Chi-square test. Frailty was prevalent among 48.2% of the subjects sampled and pre-frailty among 38.5%. Older females were found to be more likely to be frail and pre-frail. Frailty was associated with age, marital status, chronic disease, difficulty performing instrumental activities of daily living, basic activities of daily living, malnutrition and depression. The results of this study confirm that frailty is common in later life in rural areas of Lebanon and that interventions should focus on the development of strategies that are aimed at maximizing capacity, quality of life, and independence.

1. INTRODUCTION

During the past few decades, significant changes have been reported on the growth of the aging population throughout the world and the related negative impact on society. Driven by falling fertility rates and remarkable increases in life expectancy, population aging will continue to increase, and even accelerate in the decades ahead.(1) Among the 7.3 billion people worldwide in 2015, an estimated 8.5% were aged 65 and over. In this report, the number of elderly people is projected to increase by more than 60% until 2030, when there will be about 1 billion elderly people globally, equivalent to 12.0% of the total population. It is also estimated that, by 2050, people aged 65 years and over will comprise 16.7% of the total world population.(2)

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Using the proportion of elderly people as an indicator for aging, Europe historically has been the region with the most elderly population. However, Asia and Latin America are rapidly progressing through the demographic transition and population aging.[2]

Population aging in the Arab region follows a similar pattern to that taking place in the developing countries of Asia and Latin America.[3] These demographic shifts have led to a remarkable modification in the age structure of their populations and a gradual increase in the proportion of older adults.[4] This phenomenon was quoted by Palloni and colleagues as the "silent aging process", which is the outcome of a rapid and concentrated decline in fertility and infant mortality, as well as a continuing increase in life expectancy.[5]

Compared to the rest of the Arab region, the population growth in Lebanon, which stands at less than 1% per year, is expected to be among the lowest in the first half of the 21st Century. The average population growth rate in the Arab region is expected to be 2.6% and 3.8% for those 65+ and 80+, respectively.[6] It is estimated that, in Lebanon, approximately 10% of the population is currently aged 65+.[7]

1.1 Aging, Family and Chronic Diseases

With the number of elderly people growing in the Arab region, research revealed that there is a rapid increase in chronic, non-communicable diseases (NCDs) and disabilities among the older Arab populations.

Lozano, Rafael et al., based on a systematic analysis of 235 causes of death conducted for 20 age groups in 1990 and 2010, reported that cause-specific death rates combined to drive a broad shift from communicable, maternal, neonatal, and nutritional causes towards non-communicable diseases.[8] Deaths from non-communicable diseases (NCDs) increased by 42% and, in 2010, accounted for two of every three deaths worldwide. Cardiovascular diseases, lung diseases, cancer and strokes are the leading causes of death for people aged 60 and over; however, with a few notable exceptions such as diabetes and chronic kidney disease. The drivers of mortality also vary considerably per region and level of economic development.[2] Death and disability from non-communicable diseases (NCDs) are rapidly increasing in less developed countries and yielding worse outcomes than in more developed countries; some diseases that are leading to death in less developed countries are preventable or treatable in developed countries.[9]

The Health Profile of Older People in Lebanon revealed that non-communicable disease (NCDs) and degenerative diseases have become the leading causes of death and morbidity, taking over the position of communicable diseases. For instance, the national Pan Arab Project for Family Health (PAPFAM) survey, conducted by the Lebanese Central Administration of Statistics and the Ministry of Social Affairs in 2004 revealed that around three quarters of older persons in Lebanon reported at least one co-morbid medical condition and that one quarter perceived their health status as poor.[10]

For older people, having family is of particular importance.[11] As a social institution, the family unit is greatly valued and is assumed to be the main care provider for its elderly members.[12,13] Sibai et al[14] reported that increasing age and having a high number of children predicts a higher likelihood of co-residence with an adult child. Today, with there being significant changes in social status, such as women's participation in the work force, industrialization and a decline in extended families,[3] as well as high rates of emigration among youths, as a result of continuing political turmoil and economic uncertainties, the quantity and the quality of support for aging people is expected to decline in the years to come. Traditionally, ageing parents receive care from their children when they suffer debilitating chronic conditions and diseases (e.g. significant sensory losses, disability, severe arthritis, Alzheimer, Parkinson), or when they are otherwise frail.

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Further, current migration trends suggest that the rates of people living alone mirror the patterns that are observed in Western countries, with Lebanon having the highest prevalence rate of citizens living alone as compared to other Arab countries.[15]

It has been reported that 12% of adults 65+ in Lebanon live alone, and that older women (18%) are almost three times more likely to be living alone than older men (7%).[16] Among those who live with others, the majority (89%) lives in their own homes.[14,17]

1.2 Definition and Prediction of Frailty

The definition of frailty remains contested. In fact, the notion of frailty has gradually gained recognition and credibility in medical discourse through the identification that elderly people are at risk of death or of events affecting their autonomy and independence. The word frailty indicates a state of instability, with the risk of functional loss of capacity as a result of events that are sometimes quite minor.[18]

The classifications and definitions of frailty are numerous, but most of the literature considers frailty to be a condition in which a functional older person is impaired in some way and at increased risk of developing either disability, or even death, when exposed to physical or psychological stressors.[19,20,21] A frail person has a reduced functional capacity, reserve, and resistance to stressors. Frailty is an accumulation of multiple deficits, which can be social, psychological or physiological,[18,22,23] and is associated with a high prevalence of long-term adverse health-related outcomes,[24] such as a poor functional and cognitive status, falls, dependency, disability,[25] hospitalization,[26] institutionalization, and mortality.[27,28]

Rockwood notes that: "Although we all know what we think frailty looks like, and manage 'frail' patients every day, a clear definition that meets rigorous criteria of content, construct and criterion validity, remains elusive".[29] On December 7, 2012, a consensus conference convened in Orlando, Florida, USA, during which an operational definition of frailty was developed, as well as a framework for screening and treating frail persons.[30]

Frailty also includes care dependency and co-morbidity. A study conducted by Fried et al. (2004) found co-morbidity in 57.7% of cases of frailty, and care dependency in 27.2% of cases, with neither being present in 21.5% of cases.[31] Collard et al., in a systematic review, estimated that, among the general population, the prevalence of frailty ranges between 4% and 59.1%.[32] In addition, a large cross-sectional study that was conducted in 10 European countries, among randomly selected community-dwelling individuals aged 50 years and over, yielded that the proportion of frailty or pre-frailty was higher in southern Europe.[33] Estimates varied widely between high, middle and low income countries. Another study reported a prevalence of frailty in 39.2% of urban-dwelling Mexicans aged 70 and over.[34] Similarly, a prevalence of 37.7% was recorded in a Latin American and Caribbean study of people aged 60 and over.[35]

However, a cross-sectional study conducted among community-dwelling people aged 55 years and over in Abu Dhabi, UAE, recorded a high prevalence of frailty (47%) among older age groups, especially among non-married women, people who had been admitted to hospital recently, those with co-morbid conditions, those on more than five medications, and those with a lower forced expiratory volume and mini-mental state examination score.[36]

1.3 Assessing the Stages of Frailty

Other studies have been conducted to identify suitable instruments or tools for measuring stages of frailty. Most of the frail persons were being screened to determine which tools were the best for early detection of frailty, or for predicting patients' outcomes. While most studies used the Fried Phenotype

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method developed by Fried et al. in CHS study as a referral instrument to define frail older adults, other studies utilized similar tools to measure frailty.[27]

Smets et al. compared four screening instruments for geriatric assessment (abbreviated Comprehensive Geriatric Assessment, Vulnerable Elders Survey-13, Groningen Frailty Indicator and Geriatric 8) to determine their sensitivity and specificity to identify and/or classify frailty; none of these screening instruments was deemed acceptable according to a minimum of 85% for both sensitivity and specificity.[37] A study conducted by Hoogendijk et al. concerning the accuracy of five (5) simple instruments of frailty assessment yielded that PRISMA-7 registered the best accuracy, but researchers suggested that there is still a need for further research about the predictive validity and clinical utility of such a simple instrument.[38] On the other hand, Romero-Ortuno et al. conducted a large-scale study in Europe that adopted a simple instrument based on the Fried Phenotype method (The SHARE Frailty instrument) and proved that it has sufficient construct and predictive validity.[39] Furthermore, Bouillon et al., in an overview concerning the measurement of frailty, noted that: "Although there are numerous frailty scales currently in use, their reliability and validity have rarely been examined. The most evaluated and frequently used measure is the Phenotype of Frailty."[40]

The Fried Phenotype method identifies frailty by the presence of three or more of the following components: weight loss, weakness, poor endurance and energy or exhaustion, slowness and low physical activity. A critical mass of characteristics defined as three or more present for an individual was sufficient for the person to be considered frail. Persons with none of these characteristics were considered as robust, whereas those with one or two characteristics were hypothesized to be in an intermediate, possibly pre-frail, clinical stage.[27]

As regards the assessment of the prevalence of frailty and its association with selected independent variables, stages of frailty vary markedly from one individual to another and appear to be reversible, although only a small proportion of frail individuals will return spontaneously to full robustness.[41,42] Cesari et al. reported that interventions that are aimed at increasing physical activity have been shown to be effective, especially in individuals at higher risk of disability. Interventions that are aimed at improving nutrition may also be beneficial, but evidence for this is limited.[43,44]

1.4 Rural and Urban Areas

Indeed, several studies have reported that there are health disparities between people living in urban areas and those living in rural areas. Those living in rural areas are older, poorer, suffer from more severe health conditions, and there are fewer physicians to care for them, as compared to those living in cities.[45] According to the chart book, rural USA residents often have some unhealthy behaviors; often, they smoke more, exercise less, have less nutritional diets, and are more likely to be obese than urban residents.[46]

In the same context, other studies reported that rural residents, due to occupational exposure, such as toxic substances largely used in agriculture, have a greater risk of several types of cancers,[47] respiratory diseases such as chronic obstructive pulmonary disease, and musculoskeletal pain.[48] Other studies also reported that rural residents have a higher risk of neurologic diseases such as Parkinson's disease, or cognitive decline and dementia.[49] On the other hand, a few studies suggested that the rural population suffered less from health problems like cardiovascular diseases[47,50] and may have, as compared to their urban peers, a healthier lifestyle, such as a lower tobacco consumption,[51,52] greater physical activity due to the pursuance of agricultural activities, gardening, walking, fishing, hunting[53], and specific dietary habits that may be rich in fruits and vegetables,[49] but the scarce literature addressing this specific population shows inconsistent results.

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Differences in frailty between rural and urban older people have been demonstrated in developed countries. One study in a rural area in the Andes Mountains of Colombia, involving 1878 participants aged 60 years and over, elder shown to be frail, frailty appeared to be strongly associated with co-morbidities.(54) Song et al., in a Canadian study, reported that there was a difference in deficit accumulation between rural and urban areas, but this difference decreased with increased age.(55) In a large longitudinal study concerning Frailty and survival of older Chinese adults in urban and rural areas, urban dwellers showed a better survival rate than their counterparts in the rural areas.(56)

In Lebanon, with the lack of literature concerning the health status in rural areas, where most of the inhabitants are located there is an absence of policies and pension system,(57) with high cost of health insurances as well as health disparities, and where a significant percentage of Lebanese households living in poverty or below the poverty line (between 52.5 percent to 19 percent pursuant to their place of residence).(58) These facts point to the need for more investigation. Studies of health conditions of these rural populations are deemed urgent and critical.

The impaired health status of older people contributes to an increase in vulnerability, especially that the percent of people classified with a high percentage of illiteracy, there is a direct correlation between poverty and literacy.(59)

Unfortunately, little is known about the health status, characteristics and needs of older people in rural Lebanon. Most of the published studies involved older adults in nursing homes (60,61) not in primary care, for which consultation times and multidisciplinary resources were limited.

The recurring challenges in geriatrics today for all countries are identifying those elderly persons who are in need of geriatric interventions, medical care and support. In order to adapt their health care systems to meet the challenges associated with population aging, most of the developed and developing countries are showing an increased interest in addressing frailty. Frailty screening in the context of the primary and healthcare community is fundamental, in order to ensure the dignity and quality of life of older persons.(28,30)

1.5 Research Questions

1. What is the prevalence of frailty in rural Lebanon?
2. Are the prevalence rates comparable to those of other developing countries in the region?
3. Are Lebanese citizens residing in rural areas exposed to similar risk factors, as experienced in other countries?

1.6 Objectives

This study is aimed at:

1. Identifying the prevalence of frailty (full syndrome and pre-frail stage) among older people residing in rural areas of Lebanon.
2. Determining risk factors for the development of frailty among rural Lebanese residents.

2. LITERATURE REVIEW

2.1 History of Frailty

From 1986, the term "frailty" started to appear with increasing frequency in the gerontological literature, but there appears to be no consensus as to what the term actually means.

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Historically, the term frailty was fluctuating between a narrow definition and a broad one. While Stamford used the term synonymously with institutionalization,[62] frailty was defined, in 1978, in terms of a broad age range when the Federal Council on the Aging (FCA), USA, considered that it is an accompaniment of increasing age. Frailty meant reduction of physical and emotional capacities and loss of - a social - support system to the extent that the elderly individual becomes unable to maintain household or social contacts – without continuing assistance from others.[63]

In 1988, Woodhouse and associates[64] defined frail elderly people as those aged 65 years and over who depended on others for the activities of daily living and were often under institutional care. Gillick[65] (1989), defined frail elderly people as "old debilitated individuals who cannot survive without substantial help from others," emphasizing the social consequences of frailty. Others focused on frailty as measured by disability, particularly difficulties in performing activities of daily living.[3]

Both the broad and narrow definitions of frailty present problems with conceptual clarity and focus. If older persons are characterized as frail, it would be better to simply talk about problems associated with aging. In parallel, using the term for a particular outcome is more precise and hence more useful in problem description when frailty is narrowly associated with one outcome, such as institutionalization or disability. Ultimately, frailty is not "all-or-nothing." Equating frailty with aging, disability and vulnerability seems to be confounding.

Rockwood et al (1994)[67] seemed to have captured the essence of frailty when his team added the important controlling principle of a precarious, easily perturbed balance between the assets maintaining health and the deficits threatening it. The perturbation of balance causes the patient to go into hospital or other institution for care.

Furthermore, Campbell[68] defined frailty in more complex terms, as a condition or syndrome that results from a multisystem reduction in reserve capacity, to the extent that a number of physiological systems are close to, or pass, the threshold of symptomatic clinical failure. Frailty can be diagnosed clinically by measuring four key capacities required for successful interaction with the environment: musculoskeletal function, aerobic capacity, cognitive and integrative neurological function and nutritional state.

An operational definition of frailty based on a Cardiovascular Health Study (CHS) was presented by Fried and colleagues (2001)[27], in which they conceptualized frailty as a syndrome of decreased resiliency and reserves, whereby a mutually exacerbating cycle of declines across multiple systems results in a negative energy balance, sarcopenia, and diminished strength and tolerance for exertion. Accordingly, the syndrome proposes that persons exhibit exhaustion, weight loss, weak grip strength, slow walking speed, and low energy expenditure as frailty-identifying characteristics.

Alternatively, Mitnitski et al., using data from a cross-sectional Study of Health and Aging conducted in Canada, operationalized frailty as a risk index by counting the number of deficits accumulated over time (termed "frailty index (FI)"), including disability, diseases, physical and cognitive impairments, psychosocial risk factors, and geriatric syndromes.[69]

While Rockwood et al. suggest, as opposed to Fried's frailty Phenotype, that the FI is a more sensitive predictor of adverse health outcomes.[70] Xue, in his manuscript, focused on Fried's Phenotype. This 5-component phenotype method seems to be more appealing for use in a clinical setting than the FI that typically contains 30 - 70 items.[71]

In 2012, the Conference on Frailty and Sarcopenia convened in Orlando, Florida, USA, and based on the International Association of Gerontology and Geriatrics and World Health Organization White Paper, recognized that: physical frailty is an important medical syndrome, which simple screening tests

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are available for screening in order to identify persons with physical frailty or at risk of frailty. The physical frailty is a manageable condition for which all persons older than 70 years should be screened.

2.2 Frailty Differs from Aging

Aging can be defined as the decline and deterioration of functional properties at the cellular, tissue and organ level. This decrease of functional properties yields a loss of performance and homeostasis, decreased adaptability to internal and external stress, which may yield an increased vulnerability to morbidity and mortality.[72, 73]

As people age, they accumulate impairments in multiple physiological systems and become increasingly vulnerable to adverse outcomes. This process of vulnerability and decline is inextricably linked to the aging process.[29,31]

Nevertheless, the conceptualization of frailty may help in understanding the heterogeneity of functional decline observed with chronological aging.[74] With aging, some people appear to be frail at age 70 years, whereas others only reach this state in their 90s.

Some studies have reported that individual mortality risk, which can be seen as the ultimate outcome of age and frailty, can be better predicted by frailty than by chronological age.[75]

Frailty is considered as a better predictor of autonomy, institutionalization, and mortality. Studies have shown that some degree of functional loss is inevitable with old age, with the risk of adverse outcomes being established by age 70.[76]

In contrast, other studies suggest that some or all of the manifestations of frailty are caused by an underlying process, separate from aging, but is most likely to develop and progress with aging.[77]

2.3 Frailty Differs from Disability

Both disability and frailty are rather prevalent in older populations, and have common characteristics of multi-factorial nature, and share some risk factors and pathophysiological mechanisms.[78]

As the population ages, disability, defined as a social phenomenon, is becoming an increasingly important medical concept as regards public health consequences such as adverse health outcomes and increasing costs, as well as an impaired quality of life of the older population.[79]

Vitality and health statistics, based on data from the National Health Interview Survey in 1994, have reported that 20%–30% of community-dwelling adults aged older than 70 years are disabled in mobility, IADLs (tasks essential to independent household management, such as meal preparation, shopping, and managing money) and/or ADLs (basic self-care tasks, such as bathing, dressing, and eating); the frequency of disability rises steadily with age among those aged 65 years and older.[80,81]

Ferrucci et al. described the progressive versus catastrophic disability in a longitudinal view of the disablement process, and indicated that about half of the disability cases develop slowly, usually in association with chronic disease, co-morbidities, and frailty; in the other half of the cases, the disablement process is abrupt.[82]

In clinical practice, disabled elderly people are often described interchangeably as dependent, with multiple chronic conditions, co-morbid, or frail. All these terms are describing the most physically vulnerable of the elderly population in need of enhanced care.

In order to find a clinical consensus, a survey was conducted among 62 geriatricians by Fried et al.[31], which asked about terms of frailty and disability. Ninety-eight (98) percent of the respondents felt that frailty and disability are ‘not the same’. However, the causal relationships were not as clear: disability

was understood by responding geriatricians to be the cause of frailty (88%), as well as its consequence (90%). This clinical inconsistency reflects frequent overlapping of co-morbidity, disability and frailty, which was also confirmed by the results of the Cardiovascular Health Study[27] noted earlier.

These three conditions (co-morbidity, disability and frailty) seem to be interrelated, in that frailty could contribute to the progression of chronic diseases; frailty and co-morbidity could predict subsequent disability; disability may lead to frailty and worsen co-morbidity.

Research has shown that the terms co-morbidity, disability and frailty are commonly used interchangeably to identify vulnerable older people. A consensus that these are distinct clinical entities causally related with different prognosis and health care implications was argued by Fried et al.[31]

2.4 Frailty Differs from Co-morbidity

Compared with disability and frailty, co-morbidity should be the most straightforward concept to define medically.

In general, the term co-morbidity has three meanings:

1. Two or more medical conditions exist simultaneously regardless of their casual relationship;
2. Two or more medical conditions exist simultaneously and interdependently of each other, which means that one medical condition causes, is caused by, or is otherwise related to another condition in the same individual;
3. Two or more medical conditions exist simultaneously but independently of each other. In this sense, the concept of co-morbidity could be viewed as the more traditional medical definition of disease and as an interface between the geriatric paradigms of health.[31]

With aging, the presence of co-morbidity increases markedly, in large part because the frequency of individual chronic conditions rises with age. For example, after age 65, 13.4% of community-dwelling persons in Lebanon report arthritis, 36.7% hypertension, 23.1% heart disease, 21.5% diabetes, 9.7% chronic backache, and 6% a history of stroke. As a result of these diseased subpopulations within the general population in Lebanon, 77.1% older than 65 years reports at least one disease.[10] Co-morbidity is associated with higher health care utilization and expenditures, [31] and also heightens the risk of disability and mortality.[83]

Fried et al. indicated that co-morbidity could be defined as the aggregation of clinically manifest diseases present in an individual, and frailty as the aggregate of subclinical losses of reserve across multiple physiologic systems. Without dismissing that co-morbidity [84,83] and frailty [27] are independent risk factors for disability.

In the same context, in a cross-sectional study among 740 community-dwelling elderly people from the Montreal Unmet Needs Study (MUNS), Wong et al.[85] reported that 7.4% were classified as frail and that frailty was associated with age, gender, income, education, number of chronic diseases, decreased ADL disability, and IADL disability. Among those classified as frail, 29.1% had disabilities in ADLs, 92.7% in IADLs and 81.8% had co-morbidity. Researchers noted that these findings support previous studies, and provide further evidence that although frailty seems to be a distinct geriatric concept, it also overlaps with other concepts.

2.5 Pathophysiology of Frailty

Whereas several research papers had reported that genetics, disease, injuries, lifestyle and aging may be considered as causative elements of frailty,[27,86,87] other research had yielded that there were no specific causes for frailty.[88]

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In fact, some researchers consider frailty as a disorder of multiple inter-related physiological systems. When with aging there is a gradual decline in physiological reserve to compensate a disability, in frailty, this decline is accelerated. Compensatory mechanisms start failing, with high risk of homeostasis disruption and consequent negative health outcomes.[89]

Clegg et al.[28], in a paper published in The Lancet, reported that the running of the complex mechanisms of aging should be considered when addressing the pathophysiology of frailty. Aging mechanisms promote cumulative decline in multiple physiological systems, subsequent erosion of homeostatic reserves, and vulnerability to disproportionate changes in health status following relatively minor stressor events. These complex aging mechanisms are influenced by underlying genetic and environmental factors, in combination with epigenetic mechanisms that regulate the differential expression of genes in cells and may be especially important in aging.

While Fried et al. proposed an operational definition by which individuals are considered to be frail, there is also evidence that frailty may result from pathologic processes that act independently from the effects of diseases present in the elderly. Many reports indicate that frailty is associated with elevated circulating levels of markers of inflammation (C-reactive protein) and coagulation (fibrinogen and factor VIII)[90], tumor necrosis factor–alpha (TNFα), interleukin-6 (IL-6), and fibrinogen[91]. These markers were linked to frailty even in the absence of two of the most prevalent co-morbid conditions in older persons, cardiovascular disease and diabetes[90]. Such studies found associations between elevations in inflammatory markers and low muscle strength, exhaustion, slow walking speed, and low physical activity, confirming the suggestion of Szanton, Allen, Seplaki, Bandeen-Roche, and Fried in 2009[92] concerning the AL index (Allostatic Load). All major regulatory systems, such as biomarkers of cardiovascular, metabolic, endocrine, and inflammatory markers, represented in the AL index are linked to individual indicators of frailty.

Thus, frailty is independently associated with an absolute number of impaired physiological systems; as more systems show abnormal function, frailty increases, and a dysregulation in a complex network of interaction occurs between its biological elements.

Zaslvasky et al[88] suggested that the pathophysiological mechanisms of frailty run throughout three levels: Level I – Cellular Changes, Level II – System Dysregulation, and Level III – System Impairment.

2.5.1 Level Ⅰ - Cellular Changes

At the cellular level, while cumulative oxidative damage had been considered by researchers as one of the plausible causal pathways leading to frailty,[90] some studies reported that the loss of telomeres, with resultant alterations in cell division and protein production, had been strongly associated with physiological decline in older adults.[93] Multiple studies supported such a hypothesis, concerning the impact of cellular changes on frailty, although others declined it. Therefore, additional research is needed to further explore the molecular foundations of frailty.[88]

2.5.2 Level Ⅱ - System Dysregulation

A number of studies have helped to establish inflammation, hormonal dysregulation, activation of blood clotting pathways, and metabolic abnormalities as important correlates of frailty. [94,95]

Taking into consideration the inflammatory process, the aging immune system is characterized by a decline in stem cells, alterations in T-lymphocyte production, blunting of the B-cell led antibody response, and reduced phagocytic activity of neutrophils, macrophages and natural killer cells. This senescent immune system may function adequately in the quiescent state, but fail to respond appropriately to the stress of acute inflammation.[28] Evidence, reported by different studies, suggests

that inflammatory pathway alterations play a crucial pathophysiological role in the development of frailty and chronic disease. Cross-sectional data from the CHS cohort revealed that frail versus non-frail participants had significantly increased levels of CRP.[95] Other longitudinal analyses assessing the risk of frailty after 5 and 9 years of follow-up yielded similar results, demonstrating that CRP levels at the baseline were significantly associated with incident frailty.[88]

As well as the endocrine system, it is reported that alterations in anabolic hormones are closely linked to a state of multisystem senescence, and are theorized to contribute to aging and frailty. A study conducted by Capolla et al.[96] suggested that these effects are mediated through musculoskeletal impairment; however, further confirmatory research is needed. As regards the hematocoagulatory status, research reveals that activation of coagulation and fibrinolytic systems play a role in the pathophysiology of frailty in older people, which may have a significant role in preventing or at least slowing the downward cascade toward frailty.[88]

In summary, it has become apparent that inflammatory, endocrine, coagulation, and metabolic pathways are increasingly disrupted with advanced age and, to a greater extent, in those who meet the criteria for frailty. The coexistence of these unbalanced factors suggests their synergistic role in pathophysiological mechanisms leading to frailty.[88]

2.5.3 Level Ⅲ - System Impairment

The consideration of multisystem impairment in frailty is consistent with the wide range of studies on different factors associated with its development.

Musculoskeletal impairment is defined as the loss of muscle mass, strength and power classically seen in frailty that is closely associated with the development of sarcopenia, which leads to mobility loss and a decrease in gait speed.[97]

Neurocognitive impairment has been reported to be strongly associated with a functional decline. Likewise, sensory impairment, psychological factors, mood disturbance (such as depression) that lead to a high rate of disability, hospitalization and mortality, have been suggested as indicators of frailty [88,98].

2.6 Frailty as Predictor of Adverse Health Outcome

Most practitioners of medicine have been trained to focus on specific medical diseases when approaching a patient. Frailty does not fit neatly into that practice pattern, because it is almost never the basis for a ‘‘chief complaint’, and its presence is often subtle or asymptomatic.[99] Elderly patients with declining health pose significant challenges for attending physicians; often the cause or causes of the deterioration in health are not identifiable nor reversible.

The term frailty has been used to characterize the weakest and most vulnerable subset of older adults.[90] Recent research efforts have helped to better define clinical and physiological characteristics of frailty and to highlight the vulnerability of frail, older adults to poor health outcomes. Studies also sought to ascertain whether identification of frailty stages can predict any adverse outcome.

Despite a lack of consensus on definition or measurement, frailty indicators predict adverse outcomes in older people. Coelho et al.[24], in a study conducted among 252 community-dwelling elderly individuals in three northern Portuguese cities, reported that the physical components of frailty seem to have a greater importance for the prediction of adverse health outcomes.

As reported in the literature, the impact of concurrent frailty and CHF is evident, given that the prevalence of CHF increases six- to seven-fold with increasing frailty severity.[100,101] Since frailty is likely to be multidimensional, studies conducted in urban and rural areas in China, Mexico and Peru,

and urban areas in Cuba, Dominican Republic, Venezuela and India have shown that frailty is an indicator that identifies older people at risk of dependence, morbidity and mortality.[102]

A study conducted by Khandelwal et al.[103] showed that frailty also has an impact on hospitalized persons, concluding that almost a third of hospitalized older patients are frail, and have anemia, higher frequency of CHF, cognitive impairment, require longer hospital stay, and have a higher mortality rate. A similar prospective cohort study[104] conducted in hospital settings among 220 acute in-patients with arterial fibrillation, showed that compared to non-frail patients, frail ones were significantly more likely to experience embolic stroke, had a small non-significant increase in risk of major hemorrhage and had a higher risk of mortality.

While the predictions of adverse health outcome remain challengeable, studies use different approaches to determine frailty tools and to demonstrate the use of frailty identification to predict diseases and pathologies.

2.7 Tools for Predicting Frailty, and Their Validities

Numerous frailty definitions and assessment tools have been developed in clinical practice and research, and this has been the focus of many reviews and comparative studies.[37,70] In particular, the Frailty Phenotype of Fried et al.[27,70] has achieved international reputation. The method has been extensively validated in research literature.[92,105]

As noted earlier, the main advantage of Fried's method is that it requires the measurement of only five variables, namely weight loss, exhaustion, grip strength, walking speed and physical activity. [27]

In Fried's definition, frailty is defined in terms of three categories, each of which is defined by the sum of the number of individual criteria present (0: non-frail, 1 or 2: pre-frail, and 3, 4 or 5: frail), as will be explained extensively in the section on Methodology. In fact, Fried's criteria are considered as the golden standard. Several studies employed it as a referral scale to measuring the validity of all other scales concerning the screening of frailty, although many researchers had developed other tools to predict frailty, such as Frailty Index, Share Scale, Frail Scale, Groningen Frailty Index, and SOF Index, as alluded to in the following:

2.7.1 The Frailty Index

Frailty Index (FI)[106] is also a multidimensional screening instrument, which was developed around the same time as the Frailty Phenotype. The FI is measured by comparing the ratio of health deficits present within an individual to possible health deficits, using a pre-specified list of health conditions. The FI allows the inclusion of any health deficit, provided that a minimum of 30 deficits in total are included and that each deficit is associated with adverse health outcomes.

While it was argued that, compared to Fried's Frailty Phenotype, the FI is a more sensitive predictor of adverse health outcomes, due to its finer graded risk scale, and its robustness in clinical inferences with regard to the number and actual composition of the items in the FI [70], the 5-component Phenotype method is more appealing for use in a clinical setting than the FI that typically contains 30-70 items.[71]

2.7.2 The SHARE Scale

Santos-Eggimann et al. employed an approach to Fried's method in the first wave of the Survey of Health, Ageing and Retirement in Europe (SHARE), in order to establish the prevalence of frailty in middle-aged and older community-dwelling Europeans in ten different countries.[33]

Like Fried's Phenotype, SHARE embraced the following five criteria but with some modifications:

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1. **Exhaustion** was identified as a positive response to the question "In the last month, have you had too little energy to do things you wanted to do? (Yes/No)."

2. **The Shrinking** criterion was fulfilled by reporting a "diminution in the desire for food" in response to the question "What has your appetite been like?" or, in the case of a non-codable response to this question, by responding "less" to the following question: "Have you been eating more or less than usual?"

3. **Weakness** was derived from the highest of four consecutive dynamometer measurements of handgrip strength (two for each hand), applying gender and body mass index cutoffs set by Fried and associates.

4. **Slowness** was defined using mobility questions: "Because of a health problem, do you have difficulty [expected to last more than 3 months] walking 100 m?" or "… climbing one flight of stairs without resting?"

5. **The low activity** criterion was fulfilled when participants responded "one to three times a month" or "hardly ever or never" to the question "How often do you engage in activities that require a low or moderate level of energy, such as gardening, cleaning the car, or going for a walk?"

Similar to Fried's Phenotype method, one point was allocated for each fulfilled criterion: individuals with zero points were classified as non-frail, those with one or two points as pre-frail, and those with three to five points as frail.

Another study applying the SHARE instrument was conducted by Romero-Ortuno et al.[39] in the same 10 European countries, in order to validate it. Results showed that the SHARE Frailty Instrument demonstrated sufficient constructive and predictive validity of frailty in primary care.

2.7.3 The FRAIL Scale

The FRAIL scale includes 5 components: Fatigue, Resistance, Ambulation, Illness, and Loss of weight.[107] Frail Scale scores range from 0–5, with 1 point for each component; like Fried's Phenotype, where frail individuals had a score of (3-5), pre-frail ones a score of (1–2), and robust ones a score of (zero).

In this study, fatigue was measured by asking respondents how many times during the past 4 weeks they felt tired; the responses of "all of the time" or "most of the time" scoring 1 point. Resistance was assessed by asking participants if they had any difficulty walking up to 10 steps alone without resting and without aid, with "yes" responses scoring 1 point. Ambulation was assessed by asking if they had any difficulty walking several hundreds of yards alone and without aids, with "yes" responses scoring 1 point. Illness was scored as 1 point for respondents who reported 5 or more illnesses from a total of 11 illnesses. Loss of weight was scored as 1 point for respondents with a weight decline of 5% or more within the past 12 months based on self-report.

2.7.4 The Groningen Frailty Index

The Groningen Frail Index (GFI) is a 15-item instrument to determine the level of frailty, which is available in both a professional and a self-report version. It measures the loss of functions and resources in 4 domains: physical (mobility functions, multiple health problems, physical fatigue, vision, and hearing), cognitive (cognitive dysfunction), social (emotional isolation), and psychological (depressed mood and feelings of anxiety).

A cross-sectional study was conducted among 359 elderly persons residing in the northern provinces of The Netherlands, in order to identify the validity of the Groningen Frailty Index (GFI). Researchers

reported that, as compared to non-frail participants, frail older persons had higher levels of case complexity, disability, and a lower quality of life and life satisfaction. In this study, the feasibility, reliability, and validity of the self-assessment version of the GFI in home-dwelling and institutionalized elderly people were confirmed.(108)

2.7.5 The SOF index

The SOF index (109,110) identified frailty as the presence of 2 or more of the following 3 components during the second examination:

1. Weight loss (irrespective of intention to lose weight) of 5% or more between the baseline and the second examination (mean number of years between examinations 3.4 (± 0.5));
2. Inability to rise from a chair five times without using one's arms; and
3. Poor energy when answering "no" to the question "Do you feel full of energy?", as based on the Geriatric Depression Scale.

Alternatively, Kiely et al.(112), in a prospective observational study that was conducted within the framework of MOBILIZE Boston among 765 community-dwelling participants, reported that both the SOF and CHS frailty measurement instruments were similar in their ability to predict key geriatric outcomes, such as recurrent overnight hospitalization, emergency room visits, and disability, as well as chronic medical conditions, physical function, cognitive disability, and depression. Noteworthy is that both the SOF and CHS indexes provide good measures of frailty; however, the simpler SOF index may prove easier and more practical in a clinical setting.

2.8 Interventions to Prevent Frailty

Little is known about the natural course of frailty. Many studies are performed to determine the transition rates between states of frailty and to evaluate the effect of the preceding state of frailty on subsequent frailty transitions.

Also, little is known about the likelihood of transitions between different states of frailty (robust, pre-frail, frail). In the Cardiovascular Health Study (CHS), the 4-year incidence of frailty was 7.2% among participants who were initially non-frail.(27)

A prospective cohort study, which was conducted using Fried Phenotype, yielded that frailty among older persons is a dynamic process, characterized by frequent transitions between states of frailty over time. Transitions to states of greater frailty were more common than transitions to states of lesser frailty, and the probability of transitioning from being frail to non-frail was very low, even over an extended period of time. Importantly, the likelihood of transitioning between states of frailty was highly dependent on one's preceding state of frailty.(41)

The transition from the pre-frail state (latent phase) to the frail state (clinically apparent) is generally marked or provoked by a trigger event, such as an injury, an acute disease and/or psychological stress.(112)

As frailty is a progressive condition that begins with a preclinical stage, there are opportunities for early detection and prevention.(31) Since the preclinical stage of the frailty process is latent and clinically silent and not apparently linked with any disease condition, it remains difficult to detect. On the other hand, the clinical frailty stage could be detected by a suitable assessment tool.(112)

The prevention of frailty is the ultimate aim. It is possible to differentiate frailty, which seems to be reversible, from aging, which is not reversible. Interventions have been made in older people that target

correlations or specific components of frailty. Lebel et al.[113] proposed an approach to combat frailty in six different modes:

1. Adequate diet with sufficient protein, vitamin and mineral intake.
2. Regular physical exercise, practiced alone or in groups, such as stretching, walking, dancing, dynamic balance exercise and lifting weights.
3. Regular monitoring of individual basic abilities, such as walking, balance, and cognition.
4. Prevention of infections by the flu, pneumococcal and herpes zoster vaccines.
5. Anticipation of stressful events such as elective surgery
6. Rapid reconditioning after stressful events via re-nutrition and individually tailored physiotherapy.

Lang et al.[112] reported that frailty can be differentiated from aging, but unlike aging, it can be prevented and possibly reversed. In fact, in an observational cross-sectional study performed in Spain among 324 community-dwelling people aged 75 years and older, the authors suggested that low physical activity is also related to frailty and predisposes to positive energy balance and obesity. Moreover, they recommended that health professionals must encourage older people to exercise regularly and maintain good dietary habits, including both good calories and protein intake, and good micronutrient intake of fruits and vegetables.

Another review was conducted to address the role of physical activity with a focus on providing evidence for the benefits of both physical activity and exercise on preventing frailty. This review suggested that many results suggest that moderate physical activity carried out as part of everyday activities can be of substantial benefit even to frail and older persons. Vigorous exercises are not always required, while regular leisure activities – such as walking, gardening, or housekeeping – seem to be enough to reach considerable benefits.[114]

In the same context, six systematic reviews were published specifically on the benefits of exercise in frail older adults. In some cases, clinical trials did not show any convincing evidence of effectiveness, while in others the main conclusion was that exercise can improve partial aspects of functional outcomes in frail persons, such as: sit-to-stand performance, balance, agility, and ambulation. The lack of consistency among the studies is due to the differences in the definition of frailty, training protocols, and characteristics of the inactive groups. Thus, a definite conclusion has not yet been reached.[115]

Further, many studies were conducted to define the relationship between frailty and nutrition. In a review[116] of 24 studies into clinical interventions, which evaluated the effectiveness of nutrition interventions on frailty indicators, the results revealed that modification of nutrition quality, either by giving supplements or by improving diet intake, could improve strength, walking speed, and nutritional status in the majority of frail or pre-frail older adults. However, there was limited evidence on the effectiveness of intervention on inflammatory status and other biomarkers related to frailty due to limited number of studies targeting frailty biomarkers as a major outcome.

Puts et al.[117] reported that the best interventions to prevent or reduce the level of frailty, maintain functional status and quality of life, reduce healthcare costs, and enable older people to continue living at home, are currently unknown.

3. METHODOLOGY

3.1 Study Design

A cross-sectional study was conducted among 340 community-dwelling older people aged 65 years and over in a rural area in Lebanon, in the Shouf district; it was carried out between June and September 2016. Participants were recruited randomly following informed signed consent; signed by each

individual. Persons who reported dementia or who lacked capacity for consent were recruited on the basis of a relative's signed agreement. The information sheet and the consent form were being read to illiterate persons when they were invited to express their approval verbally, which was witnessed. Questions had been simplified in different manners and were repeated many times with good spelling for patients with self-reported dementia and suffering from a hearing impairment.

Noteworthy is that the participation rate was 88.33%, and the study received an approval from the ethics committee of the Institutional Review Board at Ain Wazein Medical Village, Lebanon, on May 13, 2016.

3.2 Sample Size Calculation

Several studies that focus on frailty estimate its prevalence to vary between 4% and 59.1%.[32] The estimated prevalence of frailty in Lebanon in 2013 was estimated to be 36.4% [118], which was used to calculate the sample size using the equation: $n = (z^2 \times p(1 - p))/e^2$ with a confidence level of 95%, and a ± 5% accuracy.

The population in the Shouf district at the time of the study was estimated to be 166,140 inhabitants.[119] Of the total population, 8% (13,329 persons) were reported to be elderly people[120], i.e. the target population of the study.

The required sample size was calculated to be 340. Estimating that around 10-20% of the elderly people would not agree to participate, a total of 385 elders were recruited to participate, 45 of whom did not agree; this led to the required minimum sample size of 340.

3.3 Research Process

Generating a sampling frame and selecting participants are two of the most important steps in the survey research process. However, establishing the sampling frame, which entails identifying all cases that should have an equal probability of selection, is not always possible or practical in social science surveys.[121] This is the case even in countries that have a tradition of collecting census data or large-scale survey studies.

In Lebanon, social scientists who wish to employ probability sampling in research face a number of challenges.[3] First and foremost, census data in Lebanon has not been collected accurately. As such, accurate information on the population statistics and other socio-demographic characteristics of the Lebanese population is lacking.

As far as this is concerned, and in order to select the number of subjects to be interviewed in each village, the population from 75 Municipalities was estimated, following phone calls to the head of each municipality, based on the list of eligible voters.

The sample size to be recruited from each village was calculated based on the estimated number of elderly persons in each municipality, in order to have a proportionate sample based on the number of inhabitants per village.

3.4 Questionnaire

This study was based on a comprehensive multi-component questionnaire. The questionnaire was translated back and forth from English to Arabic by two persons fluent in both languages.

A pilot trial was performed on 10 individuals prior to data collection, in order to pretest the feasibility of the questionnaire. Based to these results, a few minor changes were made. Individuals were interviewed and selected randomly from each village. Participants who met the age criteria (65 or over), and who lived in their own home were considered to be included in the study. Participants

remained anonymous and individual results were kept confidential. The interview duration of 30–40 minutes was considered acceptable. If the participant was unable to answer the entire research questionnaire, help from family members was sought. There was no response from 35 visited houses, and in 14 visited houses, all household members were aged below 65 (n=14).

3.4.1 Socio-Demographic Factors

The demographic characteristics used in this study include: age, gender, marital status and number of living children. The level of education was categorized as either illiterate, 8 years or less of education (Primary School), 8-12 years of education (Middle School), 12-15 years of education (High School), or University and advanced education.[122] Information about social status was assessed by a question about living alone, or the number of adults dwelling in the same house. Regarding main occupation, individuals were questioned if they are still working and about the longest occupation held, the responses to which were categorized into: without work (including household), agriculture sector, military sector, employee or manager, self-employed heavy activity, and self-employed light activity. The occupations were categorized according to their physical activity based on the Compendium of Physical Activity Tracking Guide 2000[123] and the Minnesota Leisure Time Activity Scale.[124].

Financial status was assessed by three questions: firstly, whether there is a monthly income. If yes, then secondly the approximate height of the income, categorized as: less than 750,000 LL, 750,000-1,500,000 LL, and 1,500,000-3,000,000 LL or more. The third and final question focused on the level of dependency on family members as a money source, income from current work, stipend, one's own savings, total dependency on family members, or more than one source of income (partially dependent).

3.4.2 Geriatric Health Characteristics

Health related characteristics were assessed by the self-related health status questionnaire (SHR), based on a 5-item scale (excellent, very good, good, fair and poor). This measure has been shown to be a reliable indicator of health assessment in Arab countries [125], as well as in developed countries.[126]

Co-morbidities were recorded by asking participants if they suffer from any chronic health conditions, such as cardiac disease, lung disease, thyroid disease, diabetes, cerebrovascular disease (CVA), dementia, Parkinson's disease, liver disease, kidney disease, osteoarthritis or any disc hernia, osteoporosis, or any other disease.

The number of medications currently consumed was estimated based on the number of medications taken on a regular basis as prescribed by a physician, "*or self prescribed";* this information was checked by the interviewer, who also documented any steroids intake or that of any diet supplements. In addition, participants were questioned if they suffer from any vision or hearing impairment, any dental difficulty, any problem of chewing or swallowing food, any urinary or stool incontinence, or chronic diarrhea. They were also asked about the number of meals they take per day and if they had any falls in the last year, as well as any recent hospitalization and, if so, the length of stay in the hospital.

Furthermore, participants were questioned if they suffer from any chronic pain and, if so, they were asked to grade their pain on a Likert pain scale ranging from 0 to 10. Likewise, answers to questions about any diet consultations, about their primary referral physician, his specialty, the number of clinic visits during the last year, as well as any major barriers to clinic visits were reported.

Health life style was assessed by posing 3 questions. Firstly, participants were questioned if they do any physical exercise, alone or in groups in their villages. Secondly, if they are an ex or current smoker, and how many packets they smoke per day and, if they have quit smoking, how many years they had

smoked. Thirdly, they were questioned about their alcohol drinking habits (never, occasionally, 2 to 3 times per week, more than 4 times per week, every day, more than 2 times per day).[127]

3.4.3 Physical Functioning Assessment

Physical functioning was investigated through the Activities of Daily Living (ADL) Arabic version, which is an instrument that screens elderly respondents for their level of physical functioning and whether they are dependent or independent in their daily activities.

The ADL scale assesses overall physical functional activities such as bathing, dressing, going to the toilet, transferring (movement), continence, and feeding. For each component a score of 0, 0.5 or 1 is given according to the status of dependency: respectively, totally dependent, needs help with some issues, or self-reliant. The total ADL score, which is the sum of the aforementioned 6 activities, lies on an ordinal scale ascending from 0 to 6, where 6 entails complete independence and 0 complete dependence. The ADL scale Arabic version was validated by Nasser et Doumit in a sample of Lebanese elderly people living in nursing homes who did not have dementia.[128]

The Lawton Instrumental Activities of Daily Living (IADL) scale is an appropriate instrument to assess independent living skills. Participants were asked about eight activities: their ability to use the telephone, shopping, food preparation, housekeeping, laundry, mode of transportation, responsibility for own medication, ability to handle their finances. Persons were scored 0 to 1 point per activity, with summary scores ranging from 0 (low function, dependent) to 8 (high function, independent). The validation of this scale was developed by Lawton and Brody in 1969[129], and by Vittengel et al, for rural areas, in 2006.[130]

3.4.4 Psychological and Cognitive Assessment

The 15-item mini GDS scale (Mini Geriatric Depression Scale) was used to detect depression disorders. It is a useful scale to detect depression among community-dwelling older people in primary care settings if the patients do not have dementia.[131] The respondents have to answer 15 questions, using Yes/No answers, describing their feeling over the past week prior to the interview. A score of 0 to five is normal, a score greater than 5 suggests depression.

The cognitive status of the participants was assessed by the Mini-Mental State Examination (MMSE),[132] which is the most commonly used screening tool for cognitive impairment worldwide. It is a 30-item scale that tests orientation, attention, immediate and short-term recall through verbal instructions. It is scored from 0 to 30. A score less than 24 indicates a mild cognitive impairment, and a score less than 17 a severe cognitive impairment. This scale, with a high sensitivity (82%) and specificity (80%).[133]

3.4.5 Nutritional Assessment

The nutritional status of community-dwelling people was assessed using the Mini Nutritional Assessment (MNA), which is the most validated screening tool for identifying nutritional status of elderly people, using a quick and easy format.[134]

It consists of six questions as regards food intake, weight loss, mobility, psychological stress or acute disease, presence of dementia or depression, and body mass index (BMI). The presence of dementia or depression was assessed through MMSE and GDS results as described above. BMI is calculated from: weight (Kg)/(height (m))^2.

The nutritional status was regarded as normal if the MNA ranged between 12 and 14; as at risk of malnutrition when it ranged between 8 and 11; and as malnourished when it was below 7.

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3.4.6 Frailty Assessment

Fried frailty criteria

Fried and colleagues developed five criteria (weight loss, exhaustion, low physical activity, slowness and weakness) to be used for identifying frail older people. A score of 0 or 1 should be given to each component of the frailty criteria according to their cut-off defined by Fried et al.[27] The sum of five criteria identifies the stage of frailty of each participant.

1. **Weight loss was assessed in two manners**

   Weight loss was assessed using a two-step process: Firstly, by posing the question: "In the last year, have you lost more than 4.5 kg unintentionally? (i.e. not due to dieting or exercise)"; this criterion was met when the participant answered "yes". Secondly, the weight of each participant was measured immediately during the interview using calibrated scales and asked to report their weight in the last year. Then, the K-weight was calculated as: (weight in previous year – current measured weight) / (weight in previous year). If $K \geq 0.05$ and the subject did not report that he/she was trying to lose weight, then the status frail as a result of weight loss was considered a "Yes".

2. **Exhaustion (poor endurance and energy)**

   When self-report indicated exhaustion, participants were required to answer the question "How often in the last week did you feel this way? by either a) I felt that everything I did was an effort; or (b) I could not get going".[135]

   Subjects had to answer if they had this feeling for: less than one day, one or two days, three or four days, or most of the time on a weekly basis; and if subjects chose the answer three or more times a week, they were categorized as frail based on exhaustion criteria.

3. **Weakness**

   Weakness was assessed by Hand Grip strength (kg) using a Dynamometer. Two consecutive measurements were taken from the hand most used. The average of 2-grip strengths was adjusted for gender and body mass index (BMI); the cut-off was dependent on BMI. If the average was below the cut-off reported by Fried et al., the frailty criterion was met.

4. **Slowness**

   Participants were asked to walk 6 meters, using a measuring stick consisting of a strip of wood with a straight edge, and the time interval in seconds was measured using a chronometer. This criterion was met when the time exceeded the cut-off reported by Fried et al., depending on gender and standing height.

5. **Physical activity**

   Physical activity was assessed using the Minnesota Leisure-Time Physical Activity Questionnaire[124], which consists of a list of 63 sports, recreational, garden, and household activities. The participant was instructed to report whether or not they performed the activity in the last 12 months. The interviewer verified any "yes" responses and asked the participant "tell me in which months you performed them", followed by "the average number of times per month" and" the average time spent on the activity each time you performed it".

The 63 activities were divided into 8 categories: walking and miscellaneous, condition exercise, water activities, winter activities, sports, lawn and garden activities, home repair activities, fishing and

hunting. The frequency of the activities was assessed month-by-month, as "average numbers of times per month". Then, the Calories expended per week were calculated, stratified by gender to indicate if a participant was frail as a result of a physical activity or not. For Men: those with expended K-calories of physical activity per week < 383, and Women: those with K-calories per week < 270, were regarded as frail.[27] The stages of frailty were defined as follows: a score of 0 means that a person is robust (not frail). Persons with a score of 1 or 2 are at intermediate risk of adverse outcomes or are considered to be pre-frail. A score of 3–5 indicates that a person is frail.

3.5 Statistical Analysis

The aim of this study was to analyze the levels of functioning across various domains. The statistical package (SPSS) v16 was used for questionnaire data entry and statistical output. Descriptive statistics was carried out to describe the demographic and health characteristics, as well as the lifestyles. Outliers were determined and excluded from analysis, in order to provide a better picture of the study at hand.

Relationships between stages of frailty and a number of continuous variables were established, using Pearson correlation. Chi-square test was also used to study bivariate correlations between explanatory variables (socio-demographic indicators, physical, nutritional and mental health status,) and frailty stages. The relationships were also established separately for men and women, given that older women are more likely to be frail.

In order to reduce the number of misclassifications, only one missing value was allowed when a person had a valid Fried score of 0–2. If a person had a valid Fried score of 3 points or more, two missing values were allowed because, according to the Fried Phenotype method, this would not cause a misclassification.

4. RESULTS

4.1 Socio-Demographic Characteristics of the Population (see Table 1)

The characteristics of the studied population are shown in Table 1. In total, 340 people (132 men (38.9%) and 208 women (61.1%)) aged between 65 and 97 years (76.2 ± 7.6 years) took part in the study; the mean age for men was slightly higher than that for women. Of the sampled people, there were 36.8% persons aged between 75 and 84 years, and 17.9% older than 85 years. Most men (88.6%) were still married; 50% of women were widowers. About 19.1% of the elderly persons lived alone in their place of residence; it should be noted here that elderly women were three times more likely to live alone than men. Of the sampled population, 41.8% had a low level of education (under 8 years) and 39.1% were illiterate. With respect to profession, about 17% of the sampled population was self-employed, 14.7% were employees or managers, 49.7% did not work at all.

Of the sampled population, 12.6% (of whom 28% were male) were still working earning an income of 750,000 LL or less, 42.9% had a monthly income in the form of a stipend from the military or COOP, 51.4% had an income of between 750,000 and 1,500,000 LL.

It is noteworthy that 47.9% of the participants who did not benefit from any monthly income were totally dependent on their family members or relatives. The mean number of living children was 4.8, with a standard deviation of 2.2; the mean number of elderly persons who lived in the same household as their children was 1.8, with a standard deviation of 1. Some elderly persons were taken care of by housekeepers.

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Table 1. Socio-demographic characteristics by gender

VARIABLES	N/%	Total (N=340)	M (N=132)	F (N=208)	p
Age Mean (SD)		**76.3(7.7)**	**77.9(7.8)**	**75.2(7.4)**	**<0.05**
Age Class	**N**	**340**	**132**	**208**	
Young Old	%	45.3	36.4	51	**<0.05**
Middle Old	%	36.8	37.1	36.5	
Old-Old	%	17.9	26.5	12.5	
Marital Status	**N**	**340**	**132**	**208**	
Single /divorced	%	5.6	0.8	8.7	**<0.05**
Married	%	59.7	88.6	41.3	
Widowed	%	34.7	10.6	50	
Living Condition	**N**	**340**	**132**	**208**	
Living Alone	%	19.1	9.1	25.5	**<0.05**
Living with others	%	80.9	90.9	74.5	
No. of living children mean (SD)		**4.8 (2.2)**	**4.8(2.0)**	**4.8(2.3)**	
No. of adults in the same household mean		**1.8 (1.0)**	**1.9(1.1)**	**1.7 (1.0)**	
Level of Education	**N**	**340**	**132**	**208**	
Illiterate	%	39.1	31.1	44.2	**<0.05**
8 years or less of Education (Primary	%	41.8	46.2	38.9	
8-12 years of education (Middle School)	%	12.6	15.2	11.1	
12-15 years of education (High School)	%	5	6.1	4.3	
University	%	1.5	1.5	1.4	
Currently working	**N**	**340**	**132**	**208**	
Yes	%	12.6	28	2.9	**<0.05**
No	%	87.4	72	97.1	
Old Occupation	**N**	**340**	**132**	**208**	
Without Work (including Household)	%	49.7	2.3	79.8	**<0.05**
Agriculture	%	8.8	18.9	2.4	
Military	%	9.4	24.2	0	
Employee or Manager	%	14.7	22	10.1	
Self- employed Heavy Activity	%	6.8	15.9	1	
Self-employed Light Activity	%	10.6	16.7	6.7	
Current Monthly Income	**N**	**340**	**132**	**208**	
Yes	%	42.9	56.8	34.1	**<0.05**
no	%	57.1	43.2	65.9	
Approximation Monthly Income	**N**	**146**	**75**	**71**	
<750,000	%	40.4	40	40.8	0.82
750,000-1,500,000	%	51.4	53.3	79.3	
1,500,000-3,000,000	%	8.2	6.7	9.9	
Source of Income	**N**	**340**	**132**	**208**	
Current work	%	8.8	15.2	4.8	**<0.05**
Stipend	%	26.8	33.3	22.6	
Using own saving	%	11.8	15.2	9.6	
More than one source (partially Dependent)	%	4.7	3	5.8	
Totally dependent on Family member	%	47.9	33.3	57.2	

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4.2 Results Regarding Health-Related Issues (see Tables 2, 3 and 4)

With respect to the self-rated health status scale, 50.6% of the studied persons perceived themselves to be in good health, 36.8% regarded their health as being poor, and about 12% considered themselves as being in very good or excellent health. Chronic illness was reported by 84.7% of the sampled population, of whom 42.9% suffered from a cardiac disease, such as CHF, valvulopathies (diseases of the cardiac valves, coronary syndrome, 32.4% had diabetes, 26.8% suffered from joint and lumbosacral disease, including osteoarthritis, discal hernia, 22.6% reported a musculoskeletal disease like osteoporosis, 17.4% reported a lung disease, 12.6% a thyroid disease, 7.6% a CVA, and only 2.6% suffered from cancer. Compared to men, elderly women suffered twice as much from joint disease and 7 times as much from musculoskeletal disease. In the same context, the proportion of women reporting pain was double that of men (55.3%); the same was true for severe pain (49.6%). There was a significant relationship between gender, chronic pain and pain severity ($p<0.05$). The mean drug intake per day was 4.9 (SD 3.2); only 7.9% of the sample population took medication that contains steroids, and 13.8% took a diet supplement. Among both men and women, 77.6% reported a vision impairment and 59.1% reported a hearing impairment. Dental problems were reported by 64.1%, who complained about inappropriate dentures; chewing problems were reported by 25%, and 4.7% reported swallowing problems. Further, 38.2% of the sampled population suffered from urinary incontinence, and only 2.9% suffered from stool incontinence. While 45.3% of the population reported at least one fall during the last year, older females (50%) seemed to have fallen more often than older men. There was a significant relationship between gender and falling ($p<0.05$).

Table 2. Geriatric health assessment and co-morbidities by gender

VARIABLES	N/%	Total (N=340)	M (N=132)	F (N=208)	p
Current Health Status	**N**	**340**	**132**	**208**	
Excellent	%	3.2	5.3	1.9	**<0.05**
Very Good	%	9.4	16.7	4.8	
Good	%	50.6	54.5	48.1	
Fair	%	32.9	20.5	40.9	
Poor	%	3.8	3.0	4.3	
Chronic Disease	**%**	**84.7**	**78.8**	**88.5**	**<0.05**
Cardiac Disease	%	42.9	45.5	41.3	0.458
Diabetes	%	32.4	23.5	38.0	**<0.05**
Joint and Lumbosacral Disease	%	26.8	13.6	35.1	**<0.05**
Musculoskeletal Disease	%	22.6	4.5	34.1	**<0.05**
Lung Disease	%	17.4	15.2	18.8	0.394
Thyroid Disease	%	12.6	5.3	17.3	**<0.05**
CVA	%	7.6	13.6	3.8	**<0.05**
Cancer	%	2.6	1.5	3.4	0.302
Parkinson Disease	%	1.5	1.5	1.4	0.956
Dementia	%	1.5	2.3	1	0.330
Kidney Disease	%	4.1	3.8	4.3	0.808
Liver Disease	%	0.9	0.0	1.4	0.166
Poly-pharmacy mean (SD)		**4.9 (3.2)**	**4.8 (3.1)**	**4.9 (3.2)**	**0.114**
Diet supplement	%	13.8	12.1	14.9	0.470
Medication with Steroids	%	7.9	8.3	7.7	0.832
Vision impairment	%	77.6	73.5	80.3	0.144
Hearing impairment	%	59.1	68.2	53.4	**<0.05**

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Table 2 (cont.). Geriatric health assessment and co-morbidities by gender

Chronic Pain	%	44.7	28	55.3	**<0.05**
Pain Scale mean (SD)		**6.2 (1.7)**	**5.4 (1.9)**	**6.4 (1.6)**	**<0.05**
Pain interpretation	**N**	**152**	**37**	**115**	
Mild pain (1-3)	%	3.9	13.5	0.9	**<0.05**
Moderate pain (4-6)	%	53.3	64.9	49.6	
Severe pain (7-10)	%	42.8	21.6	49.6	
Dental Problems	%	64.1	62.9	64.9	0.706
Chewing Problems	%	25	25.8	24.5	0.798
Swallowing Problems	%	4.7	11.4	11.1	0.930
Falls during the last year	%	45.3	37.9	50.0	**<0.05**
Urinary incontinence	%	38.2	40.9	36.5	0.420
Stool incontinence	%	2.9	3.8	2.4	0.464
Chronic diarrhea	%	4.7	3	5.8	0.246

Concerning follow up by health care providers, 57.1% reported that they always refer to the same physician. Regarding specialists, only 6.7% were regularly followed by a geriatrician regarding all health issues, 51.5% were followed by general practitioners, 23.2% by cardiologists, and 18.6% by other specialists. It is noteworthy that 3.8% of the people did not make regular visits to health care professionals. Of the sample population, 22.9% had visited physicians more than 4 times per year. Furthermore, 75.2% of the sample population indicated that they did not make such regular visits, and about 16% regarded financial and transportation problems as their major barriers.

Table 3. Referring health care and hospitalization by gender

VARIABLES	N/%	Total- (N=340)	M (N=132)	F (N=208)	p
Dietary consultation	**N**	**340**	**132**	**208**	
Yes	%	10.3%	10.6%	10.1%	0.880
No	%	89.7%	89.4%	89.9%	
Visits to the Same Physician	**N**	**340**	**132**	**208**	
No visits	%	3.8	4.5	3.4	0.494
Yes	%	57.1	53	59.6	
No	%	39.1	42.4	37	
Specialty of referral physician	**N**	**194**	**70**	**124**	
General Practitioner	%	51.5	54.3	50	0.868
Geriatrician	%	6.7	5.7	7.3	
Cardiologist	%	23.2	24.3	22.6	
Other	%	18.6	15.7	20.1	
Number of visits to clinic in last year	**N**	**340**	**132**	**208**	
Never	%	30	43.2	21.6	**<0.05**
1-3 visits	%	47.1	40.9	51	
4 and more visits	%	22.9	15.9	27.4	
Major Barriers for visits	**N**	**262**	**111**	**151**	
Financial issue	%	10.6	7.2	13.2	0.306
Transportation issue	%	5.7	3.6	7.3	
No need to visit a Doctor	%	75.2	82	70.2	
No requested appointment from physician	%	2.3	2.7	2.1	
More than 1 reason	%	6.2	4.5	7.2	

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Table 3 (cont.). Referring health care and hospitalization by gender

Number of hospitalizations mean (SD)	**0.9 (1.4)**	**0.7 (1.3)**	**0.9 (1.5)**	0.166
Length of stay in last year mean (SD)	**2.2(3.6)**	**2.4 (4.5)**	**2.0 (2.9)**	0.140

Concerning lifestyle and habits, 86.8% of the studied population did not perform any physical activity. About 10% of the people under study smoked, consuming one packet of cigarettes per day; 66.7% of the studied population quit smoking 10 years earlier.

Concerning alcohol consumption, 86.8% of the participants did not consume any alcohol at all; 12.1% did consume it occasionally.

Table 4. Lifestyle of the population by gender

VARIABLES	N/%	Total (N=340)	M*(N=132)*	F *(N=208)*	p
Number of meals per day (SD)		2.3 (0.6)	2.38 (0.6)	2.25 (0.6)	0.580
Physical Exercise	**N**	**340**	**132**	**208**	
Yes	%	13.2	15.2	12	0.408
No	%	86.8	84.8	88	
Smoke	**N**	**340**	**132**	**208**	
Ex-smoker	%	10.6	27.3	0	**<0.05**
Current smoker	%	10	15.2	6.7	
Never smoking	%	79.4	57.6	93.3	
Packets per Day	**N**	**34**	**20**	**14**	
1 packet	%	73.5	65	85.7	0.136
2 packets	%	20.6	25	14.3	
More than 2 packets	%	5.9	10	0	
Smoking Years mean (SD)		36.8(13.3)	40.7(13.4)	31.4(11.7)	**<0.05**
Quit Smoking	**N**	**36**	**36**	**0**	
Less than 5 years ago	%	11.1	11.1	0	**<0.05**
5-10 years ago	%	22.2	22.2	0	
More than 10 years ago	%	66.7	66.7	0	
Alcohol consumption	**N**	**340**	**132**	**208**	
Never	%	86.8	71.2	96.6	**<0.05**
Occasionally	%	12.1	25.8	3.4	
2-3 times per week	%	0.3	0.8	0	
More than 4 times per week	%	0	0	0	
Every day	%	0.9	2.3	0	
More than 2 times per day	%	0	0	0	

4.3 Prevalence of Frailty by Gender (Table 5)

Of the 340 people under study, one hundred sixty-four (48.2%) were frail, one hundred thirty- one (38.5%) were pre-frail, and forty-five (13.3%) were non-frail (robust).

While the pre-frail condition seemed to be comparable between men and women, other conditions revealed differences. For instance, men were often not frail (24.2% vs. 6.2%), whereas women were more often frail (56.8% vs. 34.8%).

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Table 5. Distribution of frailty sum scores according to gender

Frailty assessment	Frailty components	N (%)	Men N (%)	Women N (%)	Total	p
		N=340	N=132	N=208		
Robust	***0***	45 (13.3%)	32 (24.2%)	13(6.2%)	***13.3***	
Pre-frail	***1***	34 (10%)	19 (14.4%)	15 (7.2%)	***38.5***	***<0.05***
	2	97 (28.5%)	35 (26.5%)	62 (29.8%)		
	3	85 (25%)	28 (21.2%)	57 (27.4%)		
Frail	***4***	63 (18.5%)	14 (10.6%)	49 (23.6%)	***48.2***	
	5	16 (4.7%)	4 (3%)	12 (5.8%)		

4.4 Socio-Demographic Characteristics of Population by Frailty Stages (Table 6)

It is noteworthy that frail people seemed to be older (78.2 ± 7.4 years), more likely to be female (72%), married (51.2%), with children (5.1 ± 2.3 living children), not well educated as compared to pre-frail and non-frail people, never performed any work prior to retirement (57.9%), currently not working (94.5%), are totally dependent on their family members for support (57.3%).

Table 6. Socio-demographic characteristics distributed by frailty stages

VARIABLES	N/%	Total (N=340)	Robust (N=45)	Pre-frail (N=131)	Frail (N=164)	p
Age Mean (SD)		**76.3**	**72.7**	**75.1**	**78.2**	**<0.05**
Age Class	**N**	**340**	**45**	**131**	**164**	
Young Old	%	45.3	68.9	50.4	34.8	**<0.05**
Middle Old	%	36.8	22.2	35.1	42.1	
Old-Old	%	17.9	8.9	14.5	23.2	
Marital Status	**N**	**340**	**45**	**131**	**164**	
Single /divorced	%	5.6	4.4	6.1	5.5	**<0.05**
Married	%	59.7	75.6	64.9	51.2	
Widowed	%	34.7	20.0	29.0	43.3	
Gender	**N**	**340**	**45**	**131**	**164**	
Male	%	38.9	71.1	41.2	28.0	**<0.05**
Female	%	61.1	28.9	58.8	72.0	
Living Conditions	**N**	**340**	**45**	**131**	**164**	
Living Alone	%	19.1	22.2	16.0	20.7	0.544
Living with others	%	80.9	77.8	84.0	79.3	
No. of living children mean (SD)		4.8 (2.2)	4.3(1.9)	4.5 (2.0)	5.1(2.3)	**<0.05**
No. of adults in the household mean		1.8 (1.0)	1.9 (1.2)	1.8 (1.1)	1.8(1.0)	0.748
Level of Education	**N**	**340**	**45**	**131**	**164**	
Illiterate	%	39.1	24.4	29.0	51.2	**<0.05**
8 years or less of Education (Primary	%	41.8	46.7	45.8	37.2	
8-12 years of education (Middle	%	12.6	17.8	16.0	8.5	
12-15 years of education (High	%	5	8.9	6.1	3.0	
University	%	1.5	2.2	3.1	0	

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Table 6 (cont.). Socio-demographic characteristics distributed by frailty stages

Currently working	**N**	**340**	**45**	**131**	**164**	
Yes	%	12.6	31.1	15.3	5.5	**<0.05**
No	%	87.4	68.9	84.7	94.5	
Prior Occupation	**N**	**340**	**45**	**131**	**164**	
Without Work (including Household)	%	49.7	22.2	48.9	57.9	**<0.05**
Agriculture	%	8.8	15.6	6.9	8.5	
Military	%	9.4	24.4	9.2	5.5	
Employee or Manager	%	14.7	22.2	20.6	7.9	
Self-employed Heavy Activity	%	6.8	11.1	4.6	7.3	
Self-employed Light Activity	%	10.6	4.4	9.9	12.8	
Current Monthly Income	**N**	**340**	**45**	**131**	**164**	
Yes	%	42.9	73.3	45.0	32.9	**<0.05**
no	%	57.1	26.7	55.0	67.1	
Approximation Monthly Income	**N**	**146**	**33**	**59**	**54**	
<750,000	%	40.4	36.4	42.4	40.7	0.595
750,000-1,500,000	%	51.4	48.5	52.5	51.9	
1,500,000-3,000,000	%	8.2	15.2	5.1	7.4	
Source of Income	N	340	45	131	164	
Current work	%	8.8	17.8	9.9	5.5	**<0.05**
Stipend	%	26.8	42.2	25.2	23.8	
Using own saving	%	11.8	15.6	13.7	9.1	
More than one source (partially	%	4.7	2.2	6.2	4.2	
Totally dependent on Family member	%	47.9	22.2	45.0	57.3	

4.5 Geriatric Health Assessment, Co-morbidities, Hospitalization and Lifestyle by Frailty Stages (TABLES 7, 8 and 9)

1. Geriatric health assessment and co-morbidities

Frail participants perceived their health status as being worse than that of others (53%), had significantly more co-morbidities (92.1%), experienced cardiac diseases (52.4%), diabetes (39%), osteoporosis (26.8%) and CVA (12.2%), were prescribed numerous medications (5.1% ± 3.5), suffered very often from hearing impairment (65.2%), had consumption problems (15.2%), urinary incontinence (47.6%), had fallen during the last year (51.2%), and suffered chronic pain (60.4%). All of the aforementioned differences were statistically significant at alpha=0.05.

Table 7. Geriatric health assessment and co-morbidities by frailty stages

VARIABLES	N/%	Total (N=340)	Robust (N=45)	Pre-frail (N=131)	Frail (N=164)	p
Current Health Status	**N**	**340**	**45**	**131**	**164**	
Excellent	%	3.2	11.1	3.8	0.6	**<0.05**
Very Good	%	9.4	20.0	16.0	1.2	
Good	%	50.6	51.1	57.3	45.1	
Fair	%	32.9	17.8	21.4	46.3	
Poor	%	3.8	0	1.5	6.7	

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Table 7 (cont.). Geriatric health assessment and co-morbidities by frailty stages

Chronic Disease	**%**	**84.7**	**73.3**	**79.4**	**92.1**	**<0.05**
Cardiac Disease	%	42.9	28.9	35.9	52.4	**<0.05**
Diabetes	%	32.4	26.7	26	39	**<0.05**
Joint and Lumbosacral Disease	%	26.8	13.3	26.7	30.5	0.061
Musculoskeletal Disease	%	22.6	8.9	22.1	26.8	**<0.05**
Lung Disease	%	17.4	8.9	15.3	21.3	0.146
Thyroid Disease	%	12.6	6.7	9.9	16.5	0.103
CVA	%	7.6	2.2	3.8	12.2	**<0.05**
Cancer	%	2.6	0	2.3	3.7	0.529
Parkinson Disease	%	1.5	0	2.3	1.2	0.695
Dementia	%	1.5	0	0	3	0.097
Kidney Disease	%	4.1	0	5.3	0	0.285
Liver Disease	%	0.9	0	0.8	1.2	
Poly-pharmacy mean (SD)		4.9 (3.2)	2.5(2.5)	3.4 (3.9)	5.1 (3.5)	**<0.05**
Diet supplement	%	13.8	11.1	15.3	13.4	0.731
Medication with Steroids	%	7.9	6.7	5.3	10.4	0.271
Vision impairment	%	77.6	73.3	79.4	77.4	0.755
Hearing impairment	%	59.1	42.2	57.3	65.2	**<0.05**
Chronic Pain	%	44.7	15.6	35.1	60.4	**<0.05**
Pain Scale mean (SD)		6.2 (1.7)	5.4 (2.1)	6.0 (1.6)	6.3 (1.8)	0.494
Pain interpretation	**N**	**152**	**7**	**46**	**99**	
Mild pain (1-3)	%	3.9	2.2	1.5	3.0	0.609
Moderate pain (4-6)	%	53.3	6.7	19.8	52.5	
Severe pain (7-10)	%	42.8	6.7	13.7	44.4	
Dental Problems	%	64.1	57.8	59.5	69.5	0.135
Chewing Problems	%	25	17.1	22.1	29.3	0.172
Swallowing Problems	%	4.7	2.2	9.2	15.2	**<0.05**
Falls during the last year	%	45.3	26.7	44.3	51.2	**<0.05**
Urinary Incontinence	%	38.2	31.1	29	47.6	**<0.05**
Stool Incontinence	%	2.9	0	3.1	3.7	0.902
Chronic diarrhea		4.7	2.2	3.8	6.1	0.475

2. Health care and hospitalization

Moreover, frail participants made more clinical visits than their counterparts, and also had higher numbers of hospitalization (1.3 ± 1.7) and length of stay (3.3 days ± 4.4).

Table 8. Referring to health care and hospitalization by frailty stages

VARIABLES	N/%	Total (N=340)	Robust (N=45)	Pre-frail (N=131)	Frail (N=164)	p
Dietary consultation	**N**	**340**	**45**	**131**	**164**	
Yes	%	10.3	8.9	7.6	12.8	0.333
No	%	89.7	91.1	92.4	87.2	

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Table 8 (cont.). Referring to health care and hospitalization by frailty stages

Visits to the Same Physicians	**N**	**340**	**45**	**131**	**164**	
No visits	%	3.8	6.7	3.1	3.7	0.186
Yes	%	57.1	68.9	53.4	56.7	
No	%	39.1	24.4	43.5	39.6	
Specialty of referral physician	**N**	**194**	**31**	**70**	**93**	
General Practitioner	%	51.5	71.0	51.4	45.2	
Geriatrician	%	6.7	6.5	2.9	9.7	0.174
Cardiologist	%	23.2	12.9	28.6	22.6	
Other	%	18.6	9.7	17.2	22.7	
Number of visits to clinic last year	**N**	**340**	**45**	**131**	**164**	
Never	%	30	44.4	34.4	22.6	**<0.05**
1-3 visits	%	47.1	42.2	45.8	49.4	
4 and more visits	%	22.9	13.3	19.8	28.0	
Major Barriers for Visits	**N**	**262**	**39**	**105**	**118**	
Financial issue	%	10.6	7.7	8.6	13.6	0.335
Transportation issue	%	5.7	7.7	3.8	6.8	
No need to visit a Doctor	%	75.2	76.9	81.9	68.6	
No requested appointment from	%	2.3	2.6	0	4.2	
More than 1 reason	%	6.2	5.2	5.8	6.7	
Number of hospitalizations (SD)		0.9 (1.4)	0.4 (0.8)	0.5 (0.9)	1.3 (1.7)	**<0.05**
Length of stay in last year (SD)		2.3 (4.7)	1.1 (1.9)	1.6 (5.5)	3.3 (4.4)	**<0.05**

3. Lifestyle

With respect to the lifestyle of the frail population, physical exercise, smoking, number of packets of cigarettes consumed per day, smoking years and quitting smoking, were found to be non-significant, as compared to that of their counterparts.

Table 9. Lifestyle of the older adult population by frailty stages

VARIABLES	N/%	Total (N=340)	Robust (N=45)	Pre-frail (N=131)	Frail (N=164)	p
Mean of meals per day (SD)		2.3 (0.6)	2.4(0.6)	2.3 (0.5)	2.3(0.6)	0.289
Physical Exercise	**N**	**340**	**45**	**131**	**164**	
Yes	%	13.2	20	15.3	9.8	0.145
No	%	86.8	80	84.7	90.2	
Smoke	**N**	**340**	**45**	**131**	**164**	
Ex-smoker	%	10.6	13.3	12.2	8.5	0.423
Current smoker	%	10	15.6	9.2	9.1	
Never smoked	%	79.4	71.1	78.6	82.3	
Packets per Day	**N**	**34**	**7**	**12**	**15**	
1 packet	%	73.5	57.1	66.7	86.7	0.209
2 packets	%	20.6	28.6	33.3	6.7	
More than 2 packets	%	5.9	14.3	0	6.7	
Smoking Years mean (SD)		36.8(13.3)	40 (15.2)	32.1(14.2)	39.2(11.5)	0.588

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Table 9 (cont.). Lifestyle of the older adult population by frailty stages

Quit Smoking	**N**	**36**	**6**	**16**	**14**	
Less than 5 years ago	%	11.1	0	12.5	14.3	0.949
5-10 years ago	%	22.2	33.3	18.8	21.4	
More than 10 years ago	%	66.7	66.7	68.8	64.3	
Alcohol consumption	**N**	**340**	**45**	**131**	**164**	
Never	%	86.8	71.1	87.0	90.9	**<0.05**
Occasionally	%	12.1	26.7	10.7	9.1	
2-3 times per week	%	0.3	0	0.8	0	
More than 4 times per week	%	0	0	0	0	
Every day	%	0.9	2.2	1.5	0	
More than 2 times per day	%	0	0	0	0	

4.6 Functional, Cognitive, Psychological and Nutritional status according to the three Frailty Stages (Table 10)

With respect to the functional domain, frail male and female elderly people were very often dependent on others when performing both Basic ADL and Instrumental ADL tasks. While men's dependency was low (6.5% for ADL and 28.3% for IADL), women's dependency was somewhat high (56.8% for both ADL and IADL). With respect to the cognitive domain, frail elderly people suffered more from cognitive impairment than their pre-frail and non-frail counterparts. Any differences between males and females were found to be negligible. So far as the psychological domain is concerned, among both genders, frail participants experienced more depression (65.2%) than their pre-frail (40.7% of males and 28.6% of females) and non-frail (12.5% of males and 23.1% of females) counterparts. With respect to the nutritional status, frail participants were quite often malnourished or at risk of malnutrition. Women were found to be more malnourished than men.

Chi-square tests revealed that frailty was moderately, but significantly, associated with the Activities Daily Living (ADL) score ($\chi^2(4) = 43.367$, $p = .000$, Cramer's $V = .253$), Instrumental ADL score ($\chi^2(4) = 75.740$, $p = .000$, Cramer's $V = .334$), cognitive status (MMSE) ($\chi^2(4) = 31.018$, $p = .000$, Cramer's $V = .214$), GDS score ($\chi^2(2) = 47.976$, $p = .000$, Cramer's $V = .377$), and nutritional status (MNA) ($\chi^2(4) = 52.80$, $p = .000$, Cramer's $V = .284$).

Table 10. Functional, cognitive, psychological and nutritional status according to the three frailty stages

VARIABLES	**N/%**	**Total**	**Robust (N=45)**		**Pre-frail (N=131)**		**Frail (N=164)**		**p**
			M	**F**	**M**	**F**	**M**	**F**	
Complete Bed Rest (CBR)	**N**	**340**	**32**	**13**	**54**	**77**	**46**	**118**	
Yes	**%**	2.9	0	0	0	0	8.7	5.1	**<0.05**
No	**%**	97.1	100	100	100	100	91.3	94.9	
Activity Daily Living (ADL)	**N**	**340**	**32**	**13**	**54**	**77**	**46**	**118**	
Very Dependent	%	1.2	0	0	0	0	6.5	0.8	**<0.05**
Partially Dependent	**%**	39.4	12.5	7.7	29.6	29.9	50	56.8	
Independent	**%**	59.4	87.5	92.3	70.4	70.1	43.5	42.4	

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Table 10 (cont.). Functional, cognitive, psychological and nutritional status according to the three frailty stages

Instrumental ADL (IADL)	**N**	**340**	**32**	**13**	**54**	**77**	**46**	**118**	
Low Function status	**%**	8.2	0	0	3.7	0	28.3	11	**<0.05**
Partial Function Status	**%**	37.9	12.5	0	22.2	35.1	41.3	56.8	
High Function Status	**%**	53.8	87.5	100	74.1	64.9	30.4	32.2	
Mini Mental State Examination	**N**	**340**	**32**	**13**	**54**	**77**	**46**	**118**	
Severe Cognitive Impairment	**%**	7.4	0	0	1.9	3.9	10.9	13.6	**<0.05**
Mild Cognitive Impairment	**%**	19.4	9.4	23.1	9.3	13	23.9	28.8	
No Cognitive Impairment	**%**	73.2	90.6	76.9	88.9	83.1	65.2	57.6	
Geriatric Depression Scale (GDS)	**N**	**340**	**32**	**13**	**54**	**77**	**46**	**118**	
No Depression	**%**	53.5	87.5	76.9	59.3	71.4	34.8	34.7	**<0.05**
Depression	%	46.5	12.5	23.1	40.7	28.6	65.2	65.2	
Mini Nutritional Assessment	**N**	**328**	**32**	**13**	**53**	**76**	**42**	**112**	
Malnourished	%	22.3	0	23.1	11.3	14.5	21.4	39.3	**<0.05**
At risk of malnutrition	%	37.8	18.8	30.8	39.6	32.8	47.6	42.9	
Normal Nutritional Status	%	39.9	81.2	46.2	49.1	52.6	31.0	17.8	

4.7 Frailty Stages and Frailty Criteria (Table 11)

When comparing each of the frailty criteria under study, frail participants experienced higher percentages of frailty than their pre-frail counterparts.

Chi-square tests revealed that frailty was ***moderately associated***, but significantly, with the weight loss criterion ($\chi^2(2) = 43.448$, p = .000, Cramer's V = .370), ***relatively strongly associated*** with exhaustion ($\chi^2(2) = 1.018E2$, p = .000, Cramer's V = .547) and physical activity ($\chi^2(2) = 1.141E2$, p = .000 , Cramer's V = .579) , ***strongly associated*** with the speed test criterion ($\chi^2(2) = 1.527E2$, p = .000 , Cramer's V = .670) , and the grip strength criterion ($\chi^2(2) = 1.473E2$, p = .000, Cramer's V = .667).

Table 11. Frailty stages distributed by frailty criteria

VARIABLES	N/%	Total (N=340)	Robust (N=45)	Pre-frail (N=131)	Frail (N=164)	p
Weight loss criteria	**N**	**317**	**45**	**127**	**145**	
Frail	%	22.1	0	11.8	37.9	**<0.05**
Non-frail	%	77.9	100	88.2	62.1	
Exhaustion criteria	**N**	**340**	**45**	**131**	**164**	
Frail	%	35.6	0	13.7	62.8	**<0.05**
Non-frail	%	64.4	100	86.3	37.2	
Speed test criteria	**N**	**340**	**45**	**131**	**164**	
Frail	%	68.2	0	59.5	93.9	**<0.05**
Non-frail	%	31.8	100	40.5	6.1	
Grip strength criteria	**N**	**331**	**45**	**128**	**158**	
Frail	%	68.9	0	62.5	93.7	**<0.05**
Non-frail	%	31.1	100	37.5	6.3	
Physical activity criteria	**N**	**340**	**45**	**131**	**164**	
Frail	%	47.4	0	28.2	75.6	**<0.05**
Non-frail	%	52.6	100	71.8	24.4	

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5. DISCUSSION

The aim of this study was to describe the levels of physical, psychological and social functioning according to the three frailty stages of Fried's Phenotype method, and to identify the prevalence of frailty among community-dwelling older people in a rural area of Lebanon using a cross-sectional study. The results obtained demonstrated consistent differences for all three domains between the non-frail, pre-frail and frail older people. Frail people had poorer scores than their pre-frail and non-frail counterparts, and older people that were pre-frail had intermediate scores that came between the scores of frail and non-frail older people.

The socio-demographic characteristics of the population studied seemed to be similar to the characteristics of Lebanese elderly people that were reported by Sibai at al.[57] Females were more predominant in the sample than males, which is similar to International ratio differences between older females and males.[136] In the sample group studied, around two-thirds of the older people were married. Married men were twice as common as women. On the other hand, the number of widowed women was higher than widowed men; this data is similar to that reported by PAPFAM 2004.[10] This may translate into better support for men in their later years, assistance in their daily activities, nutritional support and companionship. Another important finding of the study is the fact that older women, like in the PAPFAM survey, were significantly more often illiterate, more often financially dependent on their family members, and more often living alone than men.

Interestingly, 28% of older men aged 65 years and over continued to work after the official age of retirement, while only 2.9% of older women did so; these percentages seem to be very close to those reported in the PAPFAM survey.[10] Further, the older people in the study often suffered from visual and hearing impairment, which may also impair their social interaction. These percentages were greatly higher than those reported by PAPFAM. Differences may be slightly exaggerated due to self-reporting of vision and hearing impairment without referring to any assessment tests.

Moreover, among females, chronic diseases, poor nutritional status, functional disability in basic ADL and IADL, depression and cognitive impairment were common and significantly more frequent than in men. Other authors reported similar findings in international and regional settings. Gender and rural differences were described by Kabir et al. in a cross-sectional study conducted in rural and urban areas in Bangladesh.[137] 80% of older women in both regions reported having more health problems than older men (only 42%). They also reported difficulties with ADL. Another study conducted by Barry et al[138] showed that women were more likely to develop depression than men.

Likewise, women in the sample population also seemed to be more disadvantaged, according to objective indicators such as number of drugs taken, number of hospitalizations and length of stay, and number of falls during the last year. However; women considered their health as being fair or poor more so than men, and also more often reported chronic pain. These findings match results of studies about SHR and pain conducted by Chemaitelly et al. in underprivileged communities in Beirut [139] and by Wranker et al.[140] respectively.

A high prevalence of frailty (48.2%) was documented for the studied sample. A high prevalence of frailty was found in the sample of community-dwelling older citizens of the Shouf area in Lebanon; this prevalence is slightly higher than that reported by Boulos et al. in a Lebanese study concerning malnutrition (36.4%)[118], but was about the same as that found in a similar study conducted in the United Arab Emirates by Al Kuwaiti et al. (47%).[36]

While different studies reported disparities between rural and urban areas,[45] a cross-sectional study conducted by Sabah et al. reported that major differences between urban and rural settings decreased in severity due to the internal and external displacement of the Lebanese population and the rapid evolution of communication services in Lebanon.[141] However, the rural population may be more

vulnerable because of limited access to health care services, and lower socio economic status; these factors have been shown to be associated with frailty.[142]

Eggimann et al., in a large-scale study conducted among community-dwelling elderly people living in ten different countries in Europe, which yielded estimates of frailty using Fried's Phenotype method[33], showed that the proportion of frailty or pre-frailty was higher in Southern than in Northern Europe. For instance, Spain showed an estimate of 27.3%, Italy 23%, Germany 12.1% and The Netherlands 11.3%; these estimates in proportions are much lower than those reported in our study.

Another study conducted by Alvarado et al. concerning frailty and health conditions among older men and women in Latin America reported a percentage of frailty that varied from 30% to 42.6% between cities where frailty was 26.7%, 39.5% and 42.6% in Bridgetown, Mexico and Santiago, respectively.[35]

The variation between studies is probably due to several reasons, such as the use of different measurement methods to determine each frailty criterion,[37,143] differences between socio-economic status of older people and political conditions in different countries, differences in life styles, such as exercise and nutrition.

Several studies reported that frailty is significantly associated with multiple factors, such as advancing age, female gender, being unmarried,[36] living alone or among subjects who reported being lonely,[143] or older people with a low level of education.[144] Similarly, in this study, frailty among Lebanese elderly people living in rural areas was associated with aging, female gender, being widowed, as well as being illiterate or having had only 8 years of education. On the other hand, living alone did not pan out as a risk factor. A number of studies have shown that living in a rural area is associated with greater co-residence and a lower prevalence of living alone among elderly people.[145] Sibai et al., in a study of living arrangements of married women in Lebanon, reported that co-residence was more frequent with unmarried than married children, with a greater likelihood of co-residency with male married children.[14] Noteworthy is that members of the same family in Lebanon live together, if not in the same household, then in the same environment, where older family members play an essential role with respect to family responsibilities.

Regarding self-reported health status, it was found that fair/poor health was more commonly reported by the female than the male participants. In addition, a significant association was observed with frailty. These findings are similar to those of Pichardo et al, who published results of a cross-sectional study conducted among 927 community-dwelling elderly people aged 70 and older in Mexico.[146]

The measurement scores for the physical domain were most favorable for the non-frail elderly people, and worst for the frail people. Pre-frail participants in our study suffered from a higher number of chronic diseases than their non-frail counterparts. The number of chronic diseases was even higher among the frail people. These results are comparable to those reported by Fried and his colleagues'.[27]

In Fried's study, cancer was the only chronic condition that was not significantly different between the frailty stages. In our study, frailty was associated with chronic disease including cardiovascular, diabetes mellitus, musculoskeletal disease and CVA. There were non-significant associations between stages of frailty and other diseases. We suggest that this non-significance was due to the self-reporting of diseases by participants. In a country such as Lebanon, people may tend to misunderstand some of their medical situations. Sometimes self-health reporting seems to be inaccurate.

Frailty was associated with falls ($p<0.05$) and hospitalization ($p<0.05$), whereby women reported more falls and more hospitalizations than men. This result is similar to a prospective cohort study conducted among British community-dwelling elderly people and similar to pooled results from studies in a systematic review and Meta-analysis.[147] Frailty was a significant and independent predictor of short-term future falls and hospitalization respectively.[148]

While a systematic review by Kojima et al. yielded that smoking can be seen as a predictor of a worsening frailty status in a community-dwelling population and that smoking cessation may potentially be beneficial for preventing or reversing frailty, smoking and quitting smoking was not significantly associated with frailty. This may be due to the small share of the population that reported to be smokers.(149)

Our findings demonstrated that physical frailty is closely tied to a significant worsening of psychosocial factors. Specifically, it was found that depressive symptoms are progressively higher in robust, pre-frail, and frail groups. We also showed a significant interaction effect of ADL, demonstrating that the performance of ADL differs depending on the combination of frailty stages. Frail subjects showed a lower level of ADL compared to non-frail individuals. Our results are consistent with those obtained by Anna M. et al., in a cross-sectional study conducted in Italy.(150) Buigues et al. reported that depression and frailty occur in a significant proportion of frail elderly individuals,(151) which was also shown in our study.

Since both frailty and cognitive impairment are increasingly prevalent with advancing age, several studies examined the association between frailty status and cognitive impairment. A longitudinal cohort study of 840 community-dwelling elderly people using Fried‘s Phenotype and MMSE reported that among the oldest people, frailty status was significantly associated with cognitive impairment.(152) This result is similar to that reported by our study, whereby frailty stages were statistically significantly associated with cognitive impairment.

In the same context, malnutrition is significantly associated with frailty in this study. Our data confirm the similar findings reported by Boulos et al. concerning the relationship between frailty and the nutritional status of community-dwelling elderly people.(118)

Finally, the association between the three frailty stages and the different criteria of Fried’s Phenotype was moderate. Frailty was associated with weight loss, moderate associated with physical activity and exhaustion, but strongly associated with gait speed test and hand grip strength. These results are similar to those reported by Kannegieter et al. in a cross-sectional study, where frail participants needed significant more time to complete the Gait Speed test, and had significant lower handgrip strength.(153)

5.1 Study difficulties and limitations

This study has several strengths, including the large representative sample, the high similarity of socio-demographics with national statistics reported by PAPFAM in 2004(10) and with a high response rate, meaning that our results can be generalized for elderly people living in other rural areas of Lebanon. In fact, few studies focused on the specific characteristics of this population and literature shows conflicting results.(45,46) Unfortunately, in Lebanon, no comparison is possible as similar data from urban settings is not available.

Moreover, to our knowledge, this is the first study reporting prevalence of frailty and associated factors in elderly Lebanese community-dwellers based on the Phenotype method (golden standard criteria) of Fried et al.(27) Also, data collection for assessment of functional, nutritional, cognitive and psychological status was based on widely used and well validated instruments.

Several limitations have to be considered in this survey. Firstly, its cross-sectional design, which does not allow the drawing of causal relationships. Secondly, even though our random sample can be considered to be representative for the rural elderly people in the Shouf district, we could not do any weighting to provide estimates of the prevalence of frailty for the whole rural population of Lebanon, due to the lack of population data in rural areas. Moreover, a part of our questionnaire was based on self-reported information, which may be affected by memory and information bias due to educational disparities (response and recall bias).

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Finally, several instruments were initially developed for western cultures, which may not be culturally sensitive to Lebanon. For example, the MNA has not been validated previously for the population of Lebanon. Thus, it may be of great importance to undergo validation studies of this important screening tool, as well as of several other specific geriatric assessment tools that have not yet been validated among the population of Lebanon.

5.2 Implications

All of the results across all domains showed the same trend, indicating more preferable scores for non-frail compared to frail older people, with intermediate scores for the pre-frail people.

The five Fried frailty criteria could help healthcare professionals to efficiently identify and treat frail elderly people, and provide indications of problems in other domains. In subsequent assessment of problems and risks, one requires a multidimensional approach; as our data has shown that often problems in various health domains co-exist. Further longitudinal research is needed to obtain a better view of which factors predict the negative consequences of frailty and what interventions could be undertaken to reverse it if possible.

6. CONCLUSION

The cross-sectional study is relevant since it expands conceptual knowledge of frailty and identifies the prevalence of frailty among elderly individuals in rural areas of Lebanon in a representative sample of the population. Thus, the present study sought to provide data on frailty, and to determine risk factors for the development of frailty, so that we can prevent its occurrence, to develop plans to address it; and to set the stage for future research projects.

Based on our findings, it was possible to conclude that the prevalence of frailty in the elderly population in the community studied is 48.2% and that frailty was associated with chronic diseases, with functional, psychological and cognitive status, as well as a higher use of healthcare resources. The study results reinforce the need for education about frailty, its consequences and treatment interventions, since it is a predictor of many adverse health outcomes such as falls, disability, and mortality.

Awareness of this problem will lead to the creation and implementation of timely preventive and adaptive measures that can delay or minimize this syndrome in the elderly population. Further, it is important for healthcare practitioners working with elderly people to recognize frailty as a risk factor for imminent adverse outcomes, even in those who appear to be aging well.

Healthcare systems in developing countries need to pay attention to the frailty syndrome, since it impacts healthcare services, morbidity and mortality. Indeed, future research is important, because many questions concerning frailty remain unanswered, such as the development of more accurate user-friendly tools to predict adverse outcomes, interventions to prevent developing it from one stage to another. Interventions must be confirmed and extended.

7. RECOMMENDATIONS

While frailty and its respective stages is a rather new concept of research in the Arab region, and because ignoring frailty syndrome has a negative impact on aging society, the health care system has a high cost on health-related complications, we recommend these issues to be addressed.

In Lebanon, because of the lack of statistics and accurate data, computing the real population of Lebanon is a dire activity. Therefore, a consensus should be held, so that accurate data on the number

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of Lebanese people and Syrian refugees is available, with respect to demographics and social characteristics of these populations.

While the majority of elderly people screened in this study, reported a lack of regularly follow-up by a healthcare professional, and some of them did not make any medical visit during the last year at all, we recommend that, in order to improve their health care management, a patient health record booklet is created that allows healthcare professionals to document progression of their patients' health conditions, vaccinations, regular geriatric assessment, recurrent hospitalization and treatment care plan. Such a booklet may enhance the traceability of health information by different healthcare professionals, especially seeing that a significantly large group of elderly people did not refer to the same physician. Another solution would be the introduction of uniform computerized health records.

While several Geriatric scales are used in Arab countries for assessing the health status of their elderly population, which were initially developed in developed countries, are validated in the English language, some have been translated into Arabic language, but they need to be validated then in the Lebanese society in different settings to ensure their reliability and specificity for general use.

While our study showed that the majority of elderly people were followed by General Practitioners for primary health care, many were unaware of their health status; many were depressed and frail and yet did not have any treatment plan to rectify the situation. We recommend that GPs and other healthcare providers be educated about frailty, including its diagnosis, factors and treatment.

Since several studies have shown that there is an interrelationship between frailty, social and psychological conditions and while Fried phenotype measure only the physical frailty of older adults. In the Arab region where some countries experience political turmoil such as war, terrorism, and other unrest, there is a need to create an appropriate measurement tool for frailty, should take the above changes and their circumstances. We suggest that these situations increase the likelihood of frailty development among vulnerable elderly people and strategies to prevent its development should be undertakes.

Since frailty has an enormous impact on acute hospital care and has been shown to be a more effective predictor of mortality, we recommend the development and implementation of special programs that aim to identify frailty stages, and the implementation of interventions to prevent its progression and to reverse it. Such programs should include education of the public and health sector about frailty. In addition, programs directed at improving nutrition, exercise and mood may today prevent it.

Since frailty is considered as a new concept in research of health care providers, it is expected that elders may misunderstand the alert symptoms which diagnosed it. Although a crucial need to enhance the level of education and knowledge of this population to ensure a better outcome seem to be pivotal.

When the frailty syndrome considered to be a reversible health condition between different frailty stages when some interventions are applied by older adults, a crucial need to identify and implement specific programs which focus on needs of frail citizens and interventions to prevent frailty syndrome and the negative transition between stages (from robust and pre-frail to frail) and impacts on society.

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Road traffic air pollution in the Greater Beirut Area (GBA), Lebanon – impact on public health: urgent need for public transport development, especially rail

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Abstract

Worldwide, more than 1.1 billion people live in urban areas that have an unhealthy air quality situation. While there are numerous sources of air-borne pollution, in most urban areas around the world, motorized road vehicles have become the single largest source of local air pollution – being responsible for nearly 50% of the emissions of smog precursors. In the Greater Beirut Area (GBA), Lebanon, there has not been a proper public transport infrastructure in place since the civil war (1975-1990). The resultant high dependency on private car use has led to significantly high levels of air pollution, which has a serious negative impact on public health. Public transport development, especially rail, is seen as a way to alleviate this problem, as well as to bring additional benefits to the country as a whole.

1. INTRODUCTION

Transport is fundamental for the social and economic development of countries, as well as for sustaining regional and global cooperation and economies. However, it is associated with a number of health-related issues, emanating from the increased levels of pollution (IPTEC, 2016).

With respect to Lebanon, a small country in the Middle East, studies show that it has the highest pollution-linked death rate, as a result of land transport (GREENPEACE MENA, 2020). According to a report titled "Toxic Air: The Price of Fossil Fuels", the estimated number of deaths in Lebanon attributable to fossil fuels was 2,700 in 2018 – a rate of four deaths per 10,000 people. The rate is one of the highest in the Middle East, alongside Egypt, which has a rate of three deaths per 10,000 people. The report, which is part of a campaign for the introduction of more renewable energy sources in the region, is particularly timely for highlighting the effect fossil fuel pollution has causing heart and lung diseases, and making residents more vulnerable to respiratory system viruses, such as coronavirus.

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Meanwhile, data from the report shows, fossil fuel-related pollution in Lebanon results in an extra 1.3 million days off work per year. While, economically, the effects of fossil fuel pollution reportedly swallow about two per cent of annual GDP, totaling approximately $1.4 billion per year. In a country that is on the brink of an economic collapse, this cost [the $1.4 billion] puts additional pressure on the finances of Lebanese citizens and their government and reveals an entirely new aspect of the economic crisis.

Noteworthy is that Lebanon is already in the midst of a debilitating economic crisis that has spiraled out of control since anti-government protests started in October 2019. The country is facing a severe dollar shortage and is seeking a bailout from the International Monetary Fund (IMF) and the release of large international aid pledges to halt its economic collapse.

2. HIGH DEPENDENCY ON PRIVATE CAR USE LEADS TO AIR POLLUTION

Road transport in Lebanon consists of road-motorized vehicles only, since there is no appropriate infrastructure for non-motorized vehicles (e.g. bicycle lanes, safe storage space, convenient and affordable bike rentals). The road-motorized vehicle types consist of Passenger Cars (PC), Light-Duty Vehicles (LDV), Heavy-Duty Vehicles (HDV) and motorcycles (see Table 1).

Table 1. Description of the vehicle categories

Vehicle category	Description
Passenger Cars (PC)	Private personal gasoline cars used for mobility, including Sport Utility Vehicles (SUV).
Light Duty Vehicles (LDV)	Gasoline vehicles with rated gross weight less than 3,500 kg, including light trucks and coaches, designed for transportation of cargo or passengers.
Heavy Duty Vehicles (HDV)	Diesel vehicles with rated gross weight exceeding 3,500 kg, including heavy trucks and coaches, designed for transportation of cargo or passengers.
Motorcycles	Includes a mixture of 2-stroke and 4-stroke engines, as well as mopeds having an engine less than 50 cc.

The vehicle fleet distribution in Lebanon is shown in Figure 1. With 85%, passenger cars make up the majority of the total vehicle fleet.

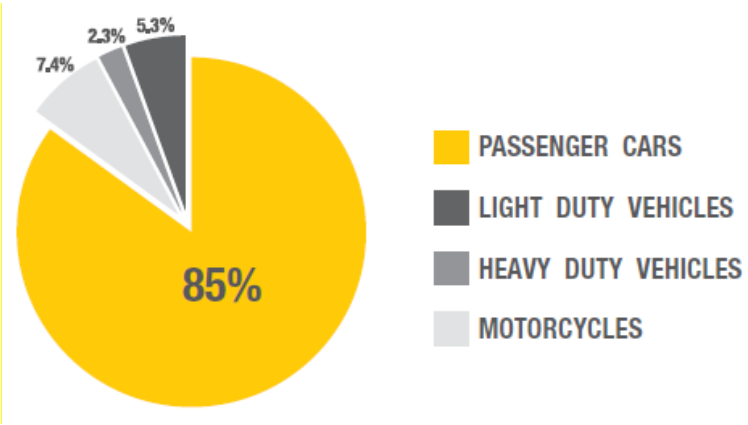

Figure 1. The vehicle fleet distribution in Lebanon by vehicle type

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Figure 2 reveals that the Lebanese vehicle fleet consists mainly of European vehicles.

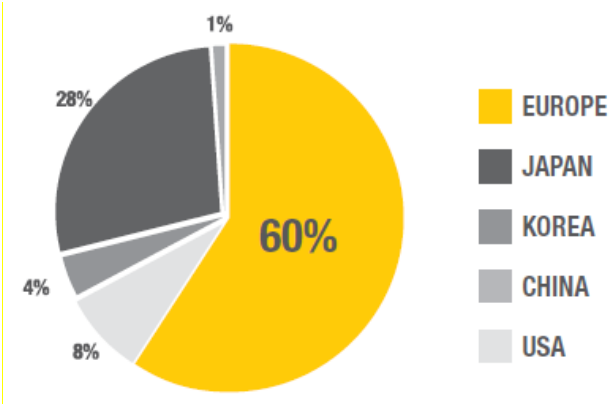

Figure 2. The vehicle fleet in Lebanon by country of origin

The high dependency on private passenger car use has seriously exacerbated road traffic congestion in Lebanon, especially in the Greater Beirut Area (GBA), turning the daily commute to/from the city center of Beirut into an ordeal for many people (Choueiri, 2015).

The GBA, which extends from Nahr-el-Damour south of Beirut to Nahr-el-Kalb north of Beirut, see Figure 3, encompasses more than 40% of the population of Lebanon.

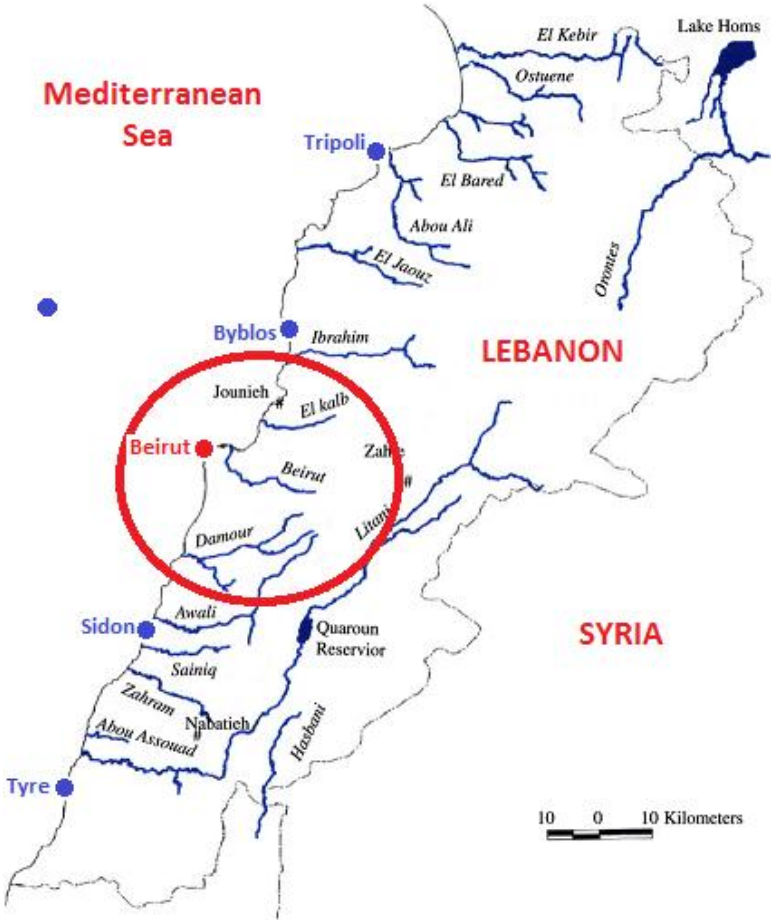

Figure 3. Map showing the main rivers in Lebanon

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Furthermore, the occurrence of a high number of road traffic accidents in the GBA results in high inherent costs to the country's economy, and places a significant burden on public health (Choueiri, 2015).

2.1 Road Traffic Congestion

The World Bank estimates that some 650,000 motorised road vehicles enter the GBA daily (Rahhal, 2019). In a report published in 2015 (BLOMINVEST, 2015), it was noted that the number of daily motorised trips within the GBA, which has a population of over 2 million people, reached some 5 million, with about 68% of the journeys made by private car, and an occupancy rate of 1.6 persons/car. The high level of private car use not only results in serious road traffic congestion, especially during the peak-hour periods, but also has large financial consequences for the economy of Lebanon, as well as a very negative impact on the environment.

2.2 Environmental Impact

The high dependency on private car use not only causes serious road traffic congestion in the Greater Beirut Area (GBA), but also has a highly negative environmental impact as regards:

- *noise:* the road traffic congestion situation is accompanied with unacceptable levels of noise, due to the high traffic density, old vehicle engines, and also an excessive use of the claxon.

  On the main roads of the Greater Beirut Area (GBA), noise levels reaching 90-95 dB have been measured, whereas the standard level is 72 dB. The measured noise levels fall into the category that is considered to cause irritation and may well also lead to health problems;

- *air pollution:* with 25% of carbon dioxide (CO_2) emissions in the Greater Beirut Area (GBA) coming from the land transport sector, which is estimated to consume about 45% of all imported fuel, the contribution of road traffic to air pollution is very significant. The high levels of air pollution in the Greater Beirut Area (GBA), which has also become a serious deterrent to tourists to visit the city, lead to high medical costs due to illnesses caused by the said air pollution.

The contribution of the different vehicle categories to Greenhouse Gases (GHG) pollutants is shown in Figure 4.

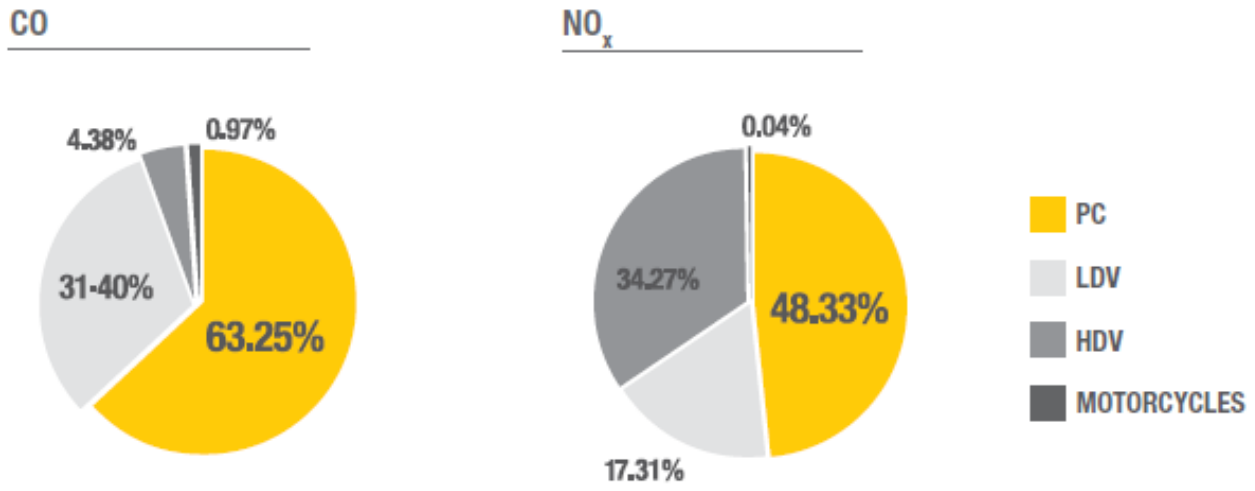

Figure 4. Contribution of the different vehicle categories to the indirect Greenhouse Gases (GHG) pollutants

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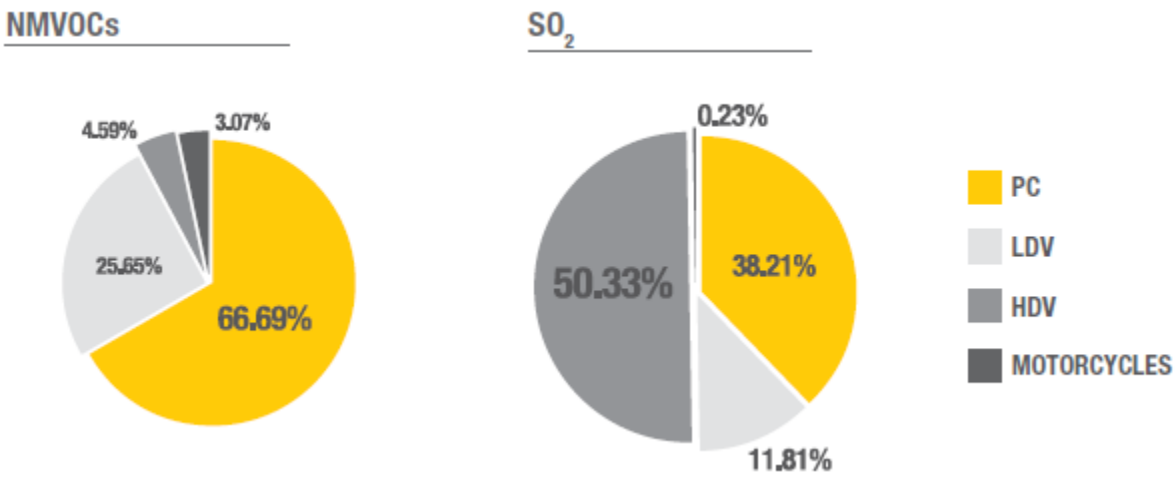

Figure 4 (cont.). Contribution of the different vehicle categories to the indirect Greenhouse Gases (GHG) pollutants

Private Cars contribute to the highest share of emissions, with 58.38% of the total road transport emissions (CO_2-eq.), while Light-Duty Vehicles (LDV), Heavy-Duty Vehicles (HDV), and motorcycles account for 17.46%, 23.81% and 0.35%, respectively. Passenger cars are the main emitting subcategory of all GHG; Light-Duty Vehicles are the second most important contributor to CH; and Heavy-Duty Vehicles to CO and N_2O, as shown in Figure 5.

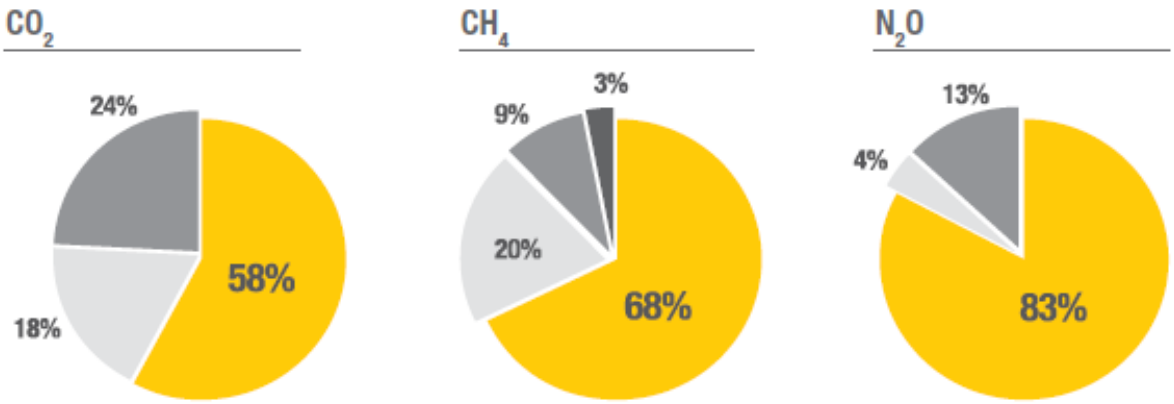

Figure 5. Contribution of the different vehicle categories to the GHG pollutants

2.2.1 Influx of Syrian Refugees – Exacerbation of Air Pollution

The road traffic congestion situation has also worsened over recent years, due to the influx of some 1.5 million refugees from neighboring Syria, who now make up roughly 25% of the resident population in Lebanon – this very large proportion is not only causing serious socio-economic problems, but is also putting a significant burden on public health in Lebanon – a country that has enough problems of its own, without having to deal with this disproportionate influx as well (see Table 2).

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Table 2. Number of displaced Syrians in Lebanon EASC (EEA, 2014) and LCRP (Gol and UN, 2017)

	Estimated Number of Displaced (EASC)	Estimated Number of Displaced (LCRP)
Displaced Syrians	1,730,000	1,500,000
Displaced Palestinians	55,000 (only Palestinian Returnees from Syria (PRS))	310,000 (including PRS & Palestinian Refugees in Lebanon (PRL))
Lebanese Returnees	50,000	35,000
Total	1,835,000	1,845,000

In 2014, the Lebanese Ministry of Environment (MoE), with support from the European Union (EU) and the United Nations Development Programme (UNDP), published the "Environmental Assessment of the Syrian Conflict & Priority Interventions (EASC)", which provided an extensive analysis of the incremental environmental impact of the conflict in Syria. As regards air quality, EASC estimations state that, in 2014, the Syrian conflict resulted in an increase of up to 20% in the emission of air pollutants in Lebanon, which has resulted in a significant degradation of air quality (EEA, 2014).

While the findings of the assessment were based on an estimated number of displaced of some 1.8 million in 2014, the same estimation of the number of displaced was still applicable in 2017, and has been adopted by the Lebanese Government as part of the "Lebanon Crisis Response Plan (LCRP) for 2017-2020" (Gol and UN, 2017) – see also Table 2.

A return of the Syrians to their own country, when the situation allows again, would bring a great alleviation in the road traffic congestion situation in Lebanon, as well as in other respects. Their arrival has led to an increase in road traffic levels of about 15-25% with an inherent rise in the number of road traffic accidents, as well as air pollution, placing a not insignificant burden on public health.

2.3 Air Pollution

The main air pollutants resulting from motorized road vehicles are: carbon dioxide (CO_2), nitrogen oxide (NO_x), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOC), suspended particulate matter (PM), ozone (O_3), carbon monoxide (CO) and lead (see also Fig. 2) (Waked et al., 2012).

Economic and environmental effects of road traffic air pollution include damage to buildings, food crops and forests. Identified health effects from road traffic air pollution include (see also Table 3):

- increased incidence of pulmonary diseases, such as asthma and emphysema;
- lung cancer, as well as cardiovascular diseases that can lead to heart attacks and strokes;
- mental retardation in children.

Table 3. Impact of main air pollutants on human health (EEA, 2014)

Pollutant	Health Impact
Particulate Matter (PM)	• Can cause/aggravate cardiovascular and lung diseases, heart attacks and arrhythmias. • Can cause cancer. May lead to arteriosclerosis, adverse birth outcome and childhood respiratory diseases. The outcome can be premature death.

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Table 3 (cont.). Impact of main air pollutants on human health (EEA, 2014)

Ozone (O_3).	• Can decrease lung function. • Can aggravate asthma and other lung diseases. • Can lead to premature death.
Nitrogen Dioxide (NO_2)	• Exposure to NO_2 is associated with increased all-cause, cardiovascular and respiratory mortality, and respiratory morbidity.
Sulphur Dioxide (SO_2)	• Aggravates asthma, and can reduce lung function and inflame the respiratory tract. • Can cause headache, general discomfort and anxiety.
Carbon Monoxide (CO)	• Can lead to heart disease and damage to the nerve system, as well as headache and fatigue.
Benzene (C_6H_6)	• Is a human carcinogen – it can cause cancer.

3. ROAD TRAFFIC AIR POLLUTION: ITS IMPACT ON PUBLIC HEALTH IN BEIRUT

A study was conducted by the Ministry of Public Works & Transport (MoPWT) and the Ministry of Environment (MoE) that examined the socio-economic impact of road traffic air pollution on public health in Beirut, Lebanon. In this respect, it addressed the following issues:

- how serious an economic and social problem is road traffic air pollution?
- what impact does road traffic air pollution have on public health?
- what are the policy options available for mitigating road traffic air pollution?
- what are the economic benefits and costs of policy options for mitigating road traffic air pollution?

Within the framework of the study:

- measurements of ambient air quality were conducted at selected locations in Beirut;
- an inventory of health consequences was made, based hospital admissions and treatment surveys;
- ambient pollution concentrations over the city of Beirut were modelled.

3.1 Air-quality measurements: outcome

Based on the measurements of ambient air quality that were conducted at selected locations in Beirut, the levels of air pollutants present were estimated. In Table 4, a summary of the estimated levels of air pollutants in Beirut due to road vehicle emissions is shown, as well as the NAAQS (National Ambient Air Quality Standards) limits for Lebanon (it should be noted that the estimates should be regarded as best rough estimates of air pollutant concentrations in Beirut as, of course, actual readings cannot be made in all locations).

Table 4. Estimated levels of air pollutants due to road vehicle emissions in Beirut, and the National Ambient Air Quality Standards (NAAQS) limits for Lebanon

Pollutant	Beirut Levels	NAAQS Limits
Particulate Matter (PM)	200 micro-g/m^3	50 micro-g/m^3 (annual average)
Ozone (O_3)	400 micro-g/m^3	235 micro-g/m^3 (annual average)

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Table 4. Estimated levels of air pollutants due to road vehicle emissions in Beirut, and the National Ambient Air Quality Standards (NAAQS) limits for Lebanon

Nitrogen Dioxide (NO_2)	12-100 micro-g/m^3 (linear model) 1,000 micro-g/m^3 (box model)	I00 micro-g/m^3 (annual average)
Carbon Monoxide (CO)	30 mg/m^3 (box model)	10 mg/m^3 (8-hour average)
Lead	1.7-13.3 micro-g/m^3 (linear model) 14 micro-g/m^3 (box model)	1.5 micro-g/m^3 (quarterly average)

3.1.1 Particulate Matter (PM)

The sampling results for particulate matter (PM) indicate that there are dangerously high levels in Beirut. Although actual measurements for particulate matter (PM) are not available for all areas in Beirut, the study assumes that the average particulate matter (PM) concentration in the city of Beirut is 200 micro-g/m^3. Experts in the field actually believe that this is a conservative value for the city as a whole.

3.1.2 Ozone

The average concentration of ozone in the city of Beirut is around 400 micro-g/m^3. According to World Health Organization (WHO) guidelines, ozone concentration levels of between 400 and 500 micro-g/m^3 are deemed unhealthy.

3.1.3 Nitrogen Dioxide, Carbon Monoxide and Lead

The modelling results for nitrogen dioxide, carbon monoxide and lead yield average concentration levels in Beirut that are all higher than prescribed by international standards.

3.2 The Impact of Particulate Matter (PM) on Public Health

In the following, the impact of the high levels of particulate matter (PM) in Beirut as regards estimated mortality, estimated excess mortality, estimated mortality costs, as well as hospital admissions is addressed.

As can be deduced from reviewed studies, an increase of 10 micro-g/m^3 in particulate matter (PM) is associated with:

- an increase of 1% in the rate of mortality;
- an increase of 2% in the total number of hospital admissions;
- an increase of 2% in hospital respiratory and cardiovascular admissions;
- an increase of 2% in emergency hospital visits for respiratory diseases.

3.2.1 Estimated Mortality

The estimated annual mortality rate in Lebanon stands at 8.2 deaths per 1,000 inhabitants, as deduced from national surveys. Without the Syrian, Palestinian and other refugees, the population of Lebanon totals about 4 million, of which one-third lives in the capital Beirut and its suburbs. It then follows that the estimated number of deaths per annum is some 33,000 in all of Lebanon, of which 11,000 in Beirut.

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3.2.2 Estimated Excess Mortality

Excess mortality refers to the increase in the number of deaths that occurs as a result of a certain increase in air pollution levels. The study found that an increase of 10 micro-g/m^3 in particulate matter (PM) concentration results in an increase of 1% in the rate of mortality. Consequently, a 10 micro-g/m^3 increase in particulate matter (PM) concentration is estimated to result in 110 excess deaths in Beirut. If a 1% increase in mortality rate (110 deaths) is associated with a 10 micro-g/m^3 increase in particulate matter (PM), then the estimated particulate matter (PM) concentration of 200 micro-g/m^3 due to road vehicle emissions in the city of Beirut, noted in Table 3, accounts for an estimated 2,200 (110 x 20) excess deaths per annum.

3.2.3 Estimated Excess Mortality Cost

Considering the lowest possible value of social life (VOSL) estimate of USD 600,000 per person in the USA, the VOSL for Lebanon, after adjusting it for the income differentials between the two countries, would be a very conservative USD 59,155 per individual. The VOSL of USD 59,155 is used in the analysis as an estimate of the average excess mortality cost (N.B.: VOSL varies with income, age, gender, as well as level of education. A VOSL of USD 59,155 is higher than the amount a judge would award as compensation for accident victims in Lebanon. The average compensation to the families of accident victims ranges from USD 20,000 to USD 50,000, depending on various socio-economic factors).

3.2.4 Hospital Admissions

The annual number of hospital admissions in Lebanon is estimated at 455,000. It is estimated that about one-third of these, or 150,000, take place in Beirut. Further:

- the average daily cost of hospitalization, for all diseases, is estimated at USD 495.29 (+/– USD 3.81 at the 95% confidence level). The average duration of hospitalization is estimated at 3.32 days (+/– 0.0376 days at the 95% confidence level). The estimated cost noted is based on the mean bill for approx. 49,000 cases of hospital admissions for various diseases;

- the average duration of hospitalization is used to estimate the average number of impaired economic activity days per individual which, for all diseases, is conservatively estimated to stand at 498,000 (i.e. 150,000 x 3.32) days in Beirut;

- the average daily wage is estimated to be approx. USD 34.00, when assuming 22 working days per month. Consequently, the total cost of impaired economic activity days for Beirut, due to hospitalization, for all diseases, is estimated at approx. USD 16,932,000 (498,000 days x USD 34.00);

- the proportion of admissions involving respiratory and cardiovascular ailments in Beirut is estimated to represent approx. 15% of the total number of hospital admissions. This is equivalent to 22,500 (i.e. 150,000 x 0.15) admissions, of which respiratory ailments represent around 37%, or 8,325 admissions. Whereas cardiovascular ailments make up the balance with 63%, or 14,175 admissions.

The aforementioned clearly shows that road traffic air pollution has a significant impact on public health in Beirut, and that measures to reduce air pollution levels are urgently needed.

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4. AN EFFICIENT AND MODERN PUBLIC TRANSPORT SYSTEM: THE SOLUTION

Mitigating the impact of road traffic air pollution on public health in Beirut requires:

- reducing exhaust-gas emission levels of all motorised road vehicles by means of technical interventions at the stage of production or retrofitting;
- encouraging people to use transport modes that have a less harmful environmental impact;
- reducing overall motorised road vehicle use.

Minimizing road traffic congestion and reducing the number of motorized road vehicles operating on the roads would be one aspect of reducing road traffic air pollution and its impact on public health. By improving road traffic flows and circulation, and providing facilities and an improved road infrastructure could alleviate some of the problem. Improving access to and mobility within the city center of Beirut, as well as enhancing the pedestrian environment and, at the same time, relieving the adverse impact of the high level of private car use are only a few examples of how the road traffic situation could be somewhat improved – but not enough.

Building more roads, demolishing buildings to make space for more cars, and adding more parking spaces will only exacerbate the problem. In a report for a road traffic congestion situation in the United Kingdom (Leigh, 2016), it is noted that such measures would only provide a temporary relief until the induced demand replenishes the space available on the roads, and also that business cases to solve road traffic congestion should be developed very carefully and take into account the prevailing situation in the specific city and country in question.

In the case of Beirut, decreasing road traffic congestion by developing more roads, for instance, is not a viable option because of its urban density and terrain, with the mountains to one side, the sea to another, and a narrow coastal strip in-between. Any road development project would require either the expropriation of land or the construction of tunnels in mountains or that of highways over the sea, all of which would be costly options. This leaves the development of an efficient and modern public transport system as the only and most favorable option, as implementation of such a system would achieve:

- a reduction in road traffic air pollution;
- a reduction in road traffic congestion;
- a reduction in expenditure on road infrastructure expansion;
- a reduction in road traffic accident rates; and
- a reduction in fuel consumption.

Foremost, because of the reduced road traffic accident rates, as well as the reduced road traffic air pollution it would bring, the implementation of an efficient and modern public transport system would significantly alleviate the very dire public health situation in Beirut.

4.1 An Efficient and Modern Public Transport System (Choueiri, 2014; Choueiri, 2018; Choueiri, 2020)

Studies to implement an efficient and modern public transport system to alleviate road traffic congestion in the Greater Beirut Area (GBA) are underway. Among these studies, also railways are looked at. In this respect, a number of routes are under focus for possible revitalization, including (see also Figure 6):

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Figure 6. Routes are under focus for possible revitalization

- *Beirut - Jounieh - Tabarja-Maameltein (- Tripoli):* in an effort to alleviate road traffic congestion in Beirut, especially on the northern approach into the city centre, studies have been conducted to see if the situation could be alleviated by implementing railway services between Beirut and Tabarja-Maameltein, and even beyond to Tripoli, using the existing coastal railway right-of-way. If sufficient funds were to become available, it has been recommended to extend the studies also to south of Beirut, at least to the coastal town of Jiyeh, near Sidon;

- *Tripoli - Abboudiyeh:* the government has assigned the Council for Development and Reconstruction (CDR) of Lebanon to look into the possibility of revitalising the railway line between Tripoli and Abboudiyeh on the Lebanese/Syrian border, in coordination with the country's Railways & Public Transport Authority (RPTA);

- *SkyWay:* another option that could be considered is to implement not a ground-borne railway system, but an elevated SkyWay system between Rafik Hariri International Airport (Beirut) and Casino du Liban (Jounieh) with intermediate stations at key locations. Such a system could alleviate the serious road traffic congestion situation near the airport and, thus, provide an efficient and reliable transport alternative for people traveling to/from the airport, as well as other destinations served by this route.

For the aforementioned railway lines to become a reality, it would take quite some time. However, the dire road traffic congestion situation needs to be alleviated much sooner – a temporary solution could come in the form of the Greater Beirut Urban Transport (GBUT) project.

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4.1.1 The Greater Beirut Urban Transport (GBUT) Project

The Greater Beirut Urban Transport (GBUT) project, by implementing a new Bus Rapid Transit (BRT) system between the densely-populated Tabarja-Maameltein/Jounieh area and Beirut, as well as feeder bus services to the trunk BRT system and within Beirut, is aimed at improving transport connectivity and mobility on the northern approach into the city centre of Beirut.

The GBUT project also includes the establishment of appropriate institutional entities for the management, operation and maintenance of this BRT system. Once effected, it would become Lebanon's first modern public transport system in decades.

5. CONCLUDING REMARKS

Lebanon is currently facing a wide array of problems, the worst since the civil war (1975-1990). Besides having to deal with the currently prevailing corona virus (Covid-19) pandemic, the country is faced by a socio-economic, financial, political, health, and humanitarian crisis, as well as the aftermath of the large-scale explosion that occurred at the Port of Beirut on 4 August 2020, which not only shook the buildings in Beirut, but also the people of this city and the country as a whole.

Since the civil war, there has not been an efficient public transport infrastructure in place in Lebanon due to a lack of funds and, therefore, there is a high dependency on private car use. This high dependency on private car use has seriously exacerbated road traffic congestion in the Greater Beirut Area (GBA), resulting in a significant increase in road traffic air pollution and accidents, which has a significant negative impact on public health.

The development of an efficient and modern public transport system with optimal services and facilities, once in place, could greatly alleviate road traffic congestion, as well as reduce road traffic air pollution and road traffic accident rates in the Greater Beirut Area (GBA) – this would enhance the health and quality of life of the people and, thus, alleviate the high burden placed on public health.

However, for all this to become a reality, the financial support from external bodies (e.g. World Bank, the European Union (EU), the European Investment Bank (EIB) and the United Nations Development Programme (UNDP)) would be very much needed.

In closing, it should be borne in mind that reducing the exhaust-gas emissions from road traffic – by implementing an efficient and modern (rail) public transport system – would not only benefit the health of the citizens of Beirut and Lebanon as a whole, but also the sustainability of the global climate we all live in and depend upon – as also the Covid-19 pandemic has shown, we all breathe the same air!

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Managing the difference between safety documentations and at-risk behaviors in the industry

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Keywords

Safety
Documentations
At-risk behaviors,
Organizations
India

Abstract

Safety is in behavior, not in documents. An overemphasis on documentation may underemphasize safety in behaviors. A mismatch of HSE documentation with that of ground behaviors would raise many serious doubts. Of course, there are many reasons as to why the safety documentation and ground realities differ in behaviors among Indian organizations. Probably they do not know how to reduce at-risk behaviors and precisely that is why the incidents do not stop. But there are transformations in the attitudes of management and HSE professionals. This article presents the qualitative and quantitative results, discusses the implications, and provides experiential conclusions of 243 HSE professionals to improve safety culture as discussed in this article, to save people from injuries and fatalities. The conclusions for the difference between safety documentation and behavioral reality include shocking factors such as missing safety messages down the levels, safety documentation to make authorities happy, poor adherence to documentation requirements, compromising risk is a regular practice, no review of unsafe behaviors for corrective action, fast businesses delivering incidents, only behavioral awareness program, not planned intervention, and not focusing on the antecedents of safe/unsafe behaviors. Recommendations are reflected for managing the difference between safety documentation and at-risk behaviors in organizations.

1. INTRODUCTION

Safety documentation in the industry is carried out practically more for fulfilling the purpose of audits, awards, and business profits, and less for an intention towards implementation of safety culture. If people feel safe and secure, they could perform better in higher standards for their companies. In developed countries, all work areas: industries, offices, universities, medical institutions, Government, and social organizations adhere to the environment, Health, and Safety (EHS) standards. But in India, an estimated 82 percent of workplaces do not comply with EHS norms, according to a

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cross-sector survey by research and consulting firm Kaybase. There is, however, a growing consciousness of the need to comply with such safety requirements (Rao, 2019).

The purpose of the Indian National Policy on Safety, Health, and Environment at Workplace is to establish a preventive safety and health culture in the country through the elimination of the incidents of work-related injuries, diseases, fatalities, disasters and to enhance the well-being of employees in all the sectors of economic activity in the country (DGFASLI, 2021). But it is noticed that workplace safety managements remain fractured without the end-user involvement which is a serious gap between theory and practice at workplace orientations (Kristen and Alicia, 2020).

It is well said that if you have a will for safety culture, there is a way. According to International Labor Organization (ILO), each year 2.78 million workers die from occupational accidents and work-related diseases, and it is estimated that lost workdays globally represent almost 4 percent of the world's GDP (International Labor Office, 2019).

OSH Code 2020 prescribed duties of employees as follows, every employee at the workplace shall take reasonable care for the health and safety of themselves and other persons who may be affected by their acts or omissions at the workplace (India Briefing, 2021). Everyone deserves safety for life at work or otherwise, not necessarily by safety rules, regulations, or systems, but with the care and kindness of everyone around by adopting behavioral safety approaches to achieve an injury-free and zero-harm work life. The importance of leading Occupational Safety and Health (OSH) indicators in complementing lagging indicators is an emerging topic for the promotion of a prevention culture in organizations (Zwetsloot, 2020).

An unsafe behavior leads to incidents and will therefore impact the business and economy of the country. The absolute safety of people, society, and business lies in behavior, not the documents of safety. The documents are on the basis of one-time safety training which is 100 percent but behaviors on the ground remain unsafe as much as 30 percent (Kaila, 2020).

The safety professionals expressed that the difference between safety documentation and ground behavior of employees was because they are trained for safety but not for behavioral safety implementation. Also, because the safety culture leadership for human values such as active care, concern, affection, humility, humanity, equality, and compassion are not being exercised for the safety of colleagues as envisaged in ISO 45001 for managing internal risk control. This gap is not being addressed urgently by top leaders of the companies (Forum of Behavioral Safety, 2021).

2. RESEARCH QUESTIONS / OBJECTIVE STATEMENT

(a) To study the factors as to why the safety documentation and ground realities differ in behaviors among Indian organizations.

(b) To discuss its implications and provide conclusions to improve safety culture, to save people from injuries and fatalities.

3. METHODOLOGY

A total of 243 HSE professionals across Indian locations reflected their viewpoint on the difference between safety documentation and ground behaviors among organizations. Both primary and secondary data were collected from the study participants with diverse backgrounds of age, experience, designation, and education. Open-ended questions-based interviews and personal in-depth discussions with HSE professionals were conducted through remote data collection techniques over a period of 6-months (October 2020 - March 2021). Thematic analysis was performed.

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Open-ended questions based on interviews and personal in-depth discussions with 250 HSE, medical, education, management, and mental health professionals were conducted through remote data collection techniques over 3 months (July-September 2020) in India from diverse locations and organizations. The responses of these professionals are presented in the following 10 themes.

4. RESEARCH FINDINGS

The study participants were asked as to why safety documentation and ground realities differ in behaviors between Indian organizations and how this difference can be managed? Their responses were categorized on the eight themes below.

1. **Missing safety message down the levels**

   Surprisingly, 90% of the study participants perceived that there was a lack of penetration of safety messages downstream. There prevails a Sab Chalta Hai (all is safe here!) Attitude by Management and Shop Floor People along with Enforcement Authority. In this cultural context, the Prime Minister emphasized that we needed to get moving from "chalta hai" to "badal sakta hai" which means a cultural change. It needs a people's movement; the Government can at most be a catalyst (The Indian Express, 2017). Management must invest in frequent safety training and orientations to improve safety knowledge among workers (Suxia et al., 2020). Missing safety messages down the levels among all employees can be very risky as it is a major lagging indicator.

2. **Safety documentation to make authorities happy**

   Almost 75% of the study participants expressed that to make regulators and statutory authorities happy, sometimes managements deceive themselves. This is salted Ahamkar tatva (ego-centric behaviors) of the company. Also, to fulfill statutory compliances, adequate resources are not provided by Indian organizations. That is why the ground reality, safety documentation, and behavior are different. This is one of the prime reasons for the lack of safety culture at workplaces. The accuracy of data documentation is still a major concern (El-Menyar, et al., 2016). If Safety documentation is done to make authorities happy, then the process of building a safety culture is surely hampered which can be very contrary to the business sustainability.

3. **Poor adherence to documentation requirements**

   As many as 80% of the study participants believed that the lack of awareness regarding documentation requirements is a reason why the safety documentation differs from the ground reality. Also, they shared that accountability for adherence to documentation requirements is very poor. This research finding is a critical lagging factor for poor safety culture at Indian sites demonstrating an unsafe mindset. Documentation is one of the key areas to determine the standard of care that employees would receive for their health and safety (Mohd Aihatram Khan et al., 2020).

4. **Compromising risk is a regular practice**

   As large as 76% of the study participants stated that compromising risk is an established practice for many Indian Organizations. This is a very serious finding of the study indicating that at-risk behaviors are a regular affair at sites that would lead to incidents and accidents. A new study finds 73% of employees fear a return to the workplace will compromise personal health and safety (Business Wire, 2020). Compromising risk as a regular practice indicates a

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pathological and reactive safety culture which is extremely risky for the workforce as well as the businesses.

5. **No review of unsafe behaviors and corrective action**

About 85% of the study participants considered that there was a lack of review of individual unsafe behaviors and suitable CAPA. Corrective and preventive action (CAPA or simply corrective action) consists of improvements to an organization's processes taken to eliminate causes of non-conformities or other undesirable situations. This demonstrates a passive outlook towards the safety of the manpower at worksites. In companies with strong safety cultures, safety is embedded in daily management; it is part of the fabric of daily activity. It infuses every interaction, every decision, and every behavior (EHS Today, 2013).

6. **Fast businesses deliver incidents**

Nearly 85% of the study participants felt that fast businesses would not sustain with incidents. They further stated that the business leaders were more competitors which boils down to less leadership for the sustainability of the business. Competition is good only if it is not at the cost of safety and killing people for profits. Almost 30 percent of our industries and systems are non-compliant due to profit and production. A safety behavior survey was made as part of the safety performance measurements to identify at-risk behaviors for the industry (Government of Western Australia, 2021).

7. **Only Behavioral awareness program, not planned intervention**

About 78% of the study participants are of the view that many organizations are misguided by false thinking that BBS is just an awareness program, failing to understand that it is a planned intervention. They wish to control incidents by just an awareness program, they fail to do so, and incidents continue to take a toll on the human life and business of the company. Safety is a matter of time for spot correction. The human side of safety takes a backseat over the business targets and profits. All at-risk behaviors existed almost all the time, but they were not corrected, or they were delayed in spot correction. As per Santosh Srivastava, Chief Safety Officer of Cairn India, “thirty percent of global fatalities are from India, as safety is enforced most of the time, lacks management commitment, and not managed in the manner like production, cost, quality. Every cultural shift takes a minimum 2 years from reactive to interdependent safety culture.” Hence, BBS focused on spot correction of all barriers and at-risk behaviors. BBS's motto is to increase the number of observers along with the increased quality of observations. On-the-spot correction together by all is live energy for organizations to excel. A behavioral safety program has limitations for its effectiveness if it is not conducted as a planned intervention on a regular basis.

8. **Not focusing on the antecedents of safe/unsafe behaviors**

Important focused group responses of the experienced HSE professionals are described below:

- Factory occupiers must take responsibility for change in the safety culture, which is missing.
- Sense of vulnerability should remain for not losing on safety actions.
- Managing heightened risk perception through ears and eyes during COVID-19 circumstances.

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- Future of safety lies in how we are going to buy people into the humanistic process like empathizing intentions among employees to be framed as organizational planned intervention.
- Discussing/sharing what factors influence employees to do at-risk behaviors at the site or anywhere
- National framework on behavioral safety in industries would greatly impact safety cultures
- Benchmarking behavioral safety by national institutions to balance lagging/leading indicators

The above-stated responses necessitate focusing on the antecedents of safe/unsafe behaviors.

5. CONCLUSIONS

The major conclusions for the underlying difference between safety documentation and behavioral reality include the seven lagging factors for the safety cultures such as missing safety messages down the levels, safety documentation to make authorities happy, poor adherence to documentation requirements, compromising risk is a regular practice, no review of unsafe behaviors and corrective action, fast businesses deliver incidents, and only behavioral awareness program, not planned intervention. These are sufficient reasons to indicate that safety culture is lagging at many sites in Indian locations. This reveals that incidents might happen, and consequences can be catastrophic, which will cause potential loss of lives or severe injury, stop operation and non-productive time, undesirable cost and expenses, destruction of equipment and defame of company reputation (Mohammed Gehad et al., 2020).

Factors that are responsible for the difference between safety documentation and ground reality, include but are not limited to:

- Missing safety messages down the levels.
- Lacking safety documentation to make authorities happy.
- Poor adherence to documentation requirements.
- Compromising risk is a regular practice.
- No review of unsafe behaviors for corrective action.
- Only behavioral awareness programs but no planned intervention.
- Poor focus on the antecedents of safe and unsafe behaviors.

The visible gaps between safety documentation and behaviors need to be addressed urgently by top leaders of companies described below, as recommended by the study participants.

1. Behavioral Safety shall be the mandatory subject on every industrial safety curriculum. At least one hour of BBS training per month shall be given to all the employees of the company including contractors. BBS implementation shall be the agenda at board level discussion and mandatory for HSE Committee. The COVID-19 outbreak has changed the approach towards workplace safety. Although robust plant design, engineering controls, SOP, and OSH organizations are essential, they will be ineffective if behavioral safety aspects are not considered (Gabhane, 2020). Any small incident even a first aid injury would call for a review of the entire BBS management system, to locate and correct what is missing.

2. Indian experiences and best practices need to be documented. There is a lot of enthusiasm to adopt BBS for injury prevention amongst the industrial fraternity, to name a few i.e. DCM Shriram, Sembcorp, GAIL, SAIL, Tata Projects, IOCL, HPCL Academia is searching for ways

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and means to introduce BBS. Statutory Authorities are looking for a private partnership that has the capability to implement BBS. Government institutions like DGFASLI, NSC are keen to find how to take it to industry and encourage incident reduction. Huge potential available in the market to mentor/coach/train and to deliver BBS. Industry and academia have recognized BBS as an effective tool for intervention in safety management. Online sessions can be conducted for promoting BBS to increase networking and outreach to various industries and educational institutions.

3. Though we are successful in promoting BBS in various industries, the real need is to address this at schools and colleges if we really wish to see the change we want. This is part of CSR in various villages; most of the companies are doing awareness on the environment, road safety, and good health. BBS must be taken to the community, as road safety and social distancing, and personal hygiene is already being tracked in our BBS checklist.
   - We cannot be safe unless the community around us is safe.
   - BBS plays a vital role in building a positive safety culture.
   - BBS can be integrated from the workplace to any place.
   - Reward safe behaviors.
   - Promote safety learning from childhood.
   - Make safety a compulsory subject in all curriculums.
   - All-out support for BBS expressed by DGFASLI, NSC, and Director NITIE
   - BBS from the workplace to any place is possible. BBS can be applied anywhere.

4. Measurement matrix and maturity ladder of BBS program are very important to exercise. For implementing BBS, a sufficient time minimum of 2-3 years should be given to achieve a good result, normally managements think that it should happen in few months. Top management's involvement and support are crucial for program success.

5. India has a very vague safety culture. Negative reinforcement is required in the unorganized sector to make it a habit leading to positive reinforcement. Zero Accident Vision is possible, and it can be achieved by Behavior-Based Safety. Companies have realized the importance of BBS, which is not industry-specific and applicable to all sectors. BBS along with traditional safety systems, industries can dream of the vision of Zero Incidents/accidents. Behavioral intervention or BBS is most successful at the time when all employees in the organizations are thinking together about the concept of BBS, starting with the leadership and the last person at the site. Top leadership and all the rest thinking together about implementing BBS to save human life from an injury. At-risk behavior is an emergency for its spot correction and a possible safe behavior for a safety culture. BBS should not rest in conversation rather get implemented. Total behavioral safety implementation for sites would require professional mentoring as well as doubt clarifying sessions. Progressive companies who have passion and innovation for safety are ready to enable their manpower for the BBS approach. If there is a will, it is possible to implement in big and widespread organizations also.

6. The Indian Industry lags in following safety protocols, and betterment can be achieved only if the people at work start understanding that their life is precious, and it is them individually who will lose if they don't remain safe. Understanding the importance of "Learning to Unlearn." There is a need to understand the importance of saying "no" to whoever if they feel that the work they have been assigned is not being carried out safely. A safety professional shared, "as a 4th Engineer, I have seen a Cadet dying in the Container because he wasn't properly equipped with PPE and was asked by his senior to go down, all he had to say was "No." Understanding

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that an accident does not ask if you are highly experienced or if you have a training certificate. It's you who have to take a call."

7. There is a need to use the leading and lagging indicators for rating BBS while implementing. It is well said by a safety officer, "being as a shop floor person (manufacturing/process unit) if the shop floor people are safe, then the organization is safe." To make them understand their safety, daily interaction/training/feedback is a must and make BBS a humanistic movement and emotionally connect people at the site in order to succeed fully.

8. Post-COVID, the workplace concept is changing. New concerns in safety, health, and psychosocial relations arise. BBS must transform to address such concerns. e. g. Ergonomics, workaholic culture. There is plenty of scope for MSME and the service sector to adopt BBS. The challenge would be to offer BBS to smaller groups or to even individuals. Post COVID-19, behavior-based-safety (BBS) became a more popular approach to safety management, which sees the main cause of accidents in unsafe behavior or act (Gabhane, 2020). How much value is being delivered by the BBS implementation is measured by the percentage of participation of observers. That is how many people are being observed and spot-corrected by each observer, divided by what was the goal of participation for observers in each department. BBS means an instant spot correction of at-risk behavior by everyone at the site; therefore, an observer is trained for a moment of correcting, and an organization is trained to sustain it. A leadership of dreams and determination can do it.

9. What is lacking in sites at the department level, is as follows:
   - Appreciation of BBS observers
   - Observer's positive approach of correction as big brother
   - Developing more observers
   - Making observation round daily
   - Goal setting by departments for a number of observations by each observer to calculate % of observer's participation
   - Alternatively, you may decide at the steering team for inclusion of observer name in the BBS checklist, for those who do at-risk behaviors repeatedly.

10. What is organizationally lacking somewhere is Humanistic Behaviorism and Mindfulness (Safety with Human touch & actively caring). We need to refresh people with these basic aspects of behavioral safety periodically. In this regard, a 10-point organizational BBS implementation commitment test for zero-harm actions (Kaila, 2020) is recommended:
    - Has your CEO issued a circular to all employees for BBS implementation?
    - Has your organization displayed BBS banners across all work areas?
    - Has your organization formed the BBS steering team?
    - Is the BBS steering team meeting every month and reviewing progress?
    - Are all employees and workmen aware of the BBS concept of observations-spot-correction?
    - Is the organization calculating and displaying the BBS scoreboard each month?
    - Has the organization issued a BBS identity sticker to all observers to fix on the helmet?
    - Do all HODs make BBS rounds each day?
    - Has BBS implementation affected reduced incidents at sites?
    - Has BBS implementation affected reduced barriers in safety?

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11. Risk perception is important especially when we have low safety consciousness in the majority of the contract associates. Timely observation by employees is precious for someone to be saved from injuries. So, BBS is to be a part of the Risk Assessment and HAZOP study as an integral OHS management system. BBS means Better Business Sense.

To conclude, it is imperative that the safety documentation is in tandem with ground realities. Mismatch of HSE documentation with that of ground behaviors would raise many serious doubts about the compliances of safety rules and regulations on part of everyone concerned such as the company management, factory owner, auditors, safety department, factory inspectorates, etc. Finally, this hampers business sustainability and exposes manpower to risks as a threat to life. Hence, safety is to be implemented with an outlook of humanity and to be managed with humanistic philosophy more actively, it would save human beings from fatalities and business from losses. Needless to mention that the insurance, as well as enforcement agencies, take cognizance of this research and its implications for reinforcement of safety culture in workplace establishments.

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X _____ _____
Applicant Signature | Date

FOR MID/HIGH SCHOOLERS ONY: *WSO subscribes to the Family Educational Rights and Privacy Act (FERPA) philosophy in protecting student privacy and information. WSO may disclose "directory" information such as a student's name, WSO Student Chapter affiliation, name of school, grade in school, etc., along with group or individual photos in WSO NewsLetters, NewsFlashes, eNews, on WSO website, and on WSO's social media accounts.*

❑ My student has permission to participate as outlined above.

❑ My student has permission to participate with exclusions: _____

X _____ _____
Parent/Guardian Signature (Mid/High Student) | Date

X _____ _____
WSO Student Chapter Mentor Signature **[IF APPLICABALE]** | Date

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World Safety Organization

Code of Ethics

Members of the WSO,
by virtue of their acceptance of membership
into the WSO,
are bound to the following Code of Ethics
regarding their activities associated with the WSO:

Members must be responsible for
ethical and professional conduct in relationships
with clients, employers, associates, and the public.

Members must be responsible for professional competence in
performance of all their professional activities.

Members must be responsible
for the protection of professional interest, reputation, and
good name of any deserving WSO member
or member of other professional organization involved in
safety or associate disciplines.

Members must be dedicated to professional development of new
members in the safety profession
and associated disciplines.

Members must be responsible
for their complete sincerity in professional service to the
world.

Members must be responsible for continuing improvement and
development of professional competencies
in safety and associated disciplines.

Members must be responsible
for their professional efforts to support the WSO motto:

"Making Safety a Way of Life…Worldwide."

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