A multi-criteria methodology for evaluating alternative ultrasound devices

Supplemental material

We propose the following meanings attributed to the hierarchy elements (listed in the order they appear in the hierarchy) to make the pairwise comparisons and properly formulate the questions to the decision-maker. In particular, the syntax used to define the last level elements is: Element: benefit [indicators (standards)]. The meanings of the other elements do not provide indicators and standards because they inherit those of the connected lower level elements. An example is “*Accessibility and reach zones*: can be used by a larger number of people from a population with the widest range of characteristics to achieve a specified goal in a specified context of use [work area clearance, size of objects, action demand, coordination demand, stability demand (ISO 26800, 2011; ISO 14738, 2002; ISO 11064-4, 2013)]”, where “*Accessibility and reach zones”* is a Sub-criterion, “can be used by a larger number of people from a population with the widest range of characteristics to achieve a specified goal in a specified context of use ” is the benefit, “work area clearance” is an indicator and “ISO 14738, 2002” is a “standard”.

The questions for the pairwise comparisons of how to evaluate the elements with respect to each final level criterion can be defined as in this example: “How much more is *Efforts and movements* preferred over *Postures* under the *Biomechanics* Criterion?”. The value obtained from this comparison is included in the corresponding matrix. Based on the syntax specified, it is possible to construct the questions for all pairwise comparisons.

The questions for the pairwise comparisons of how to evaluate the alternatives with respect to the element above can be defined as in the following: “How much does ALTERNATIVE X benefit over ALTERNATIVE Y under *Element*?”. For example, a question is “How much less time and other resources does ALTERNATIVE 1 (wireless device) require to perform an ultrasound then ALTERNATIVE 2 (portable device) under *Efficiency*?”.

All matrices of pairwise comparison (element and alternative evaluation matrices) obtained in the case study are in the following.

To verify the consistency of comparisons, we calculated a measure called Consistency Ratio (CR) for each matrix. In general, a CR of 0.10 or less is considered acceptable. If the CR is higher, it means that the input values are not consistent, i.e. are not reliable, and so the comparisons need to be revised in order to improve their consistency. Since all matrices of this case study have a CR ≤ 0.10, the decision maker group has been sufficiently consistent in making pairwise comparisons.

# Meanings of the Strategic-Criteria:

* *Ergonomics, health and safety performance*: allows to perform ultrasounds with a higher level of comfort, safety and health for the sonographer, considering the connected Criteria;
* *Production performance*: allows to perform more and better ultrasounds, considering the connected Criteria.

# Meanings of the Criteria

* *Biomechanics*: allows a less risky and more comfortable performing ultrasounds from a biomechanical point of view, considering the connected Sub-criteria;
* *Anthropometry*: allows a less risky and more comfortable performing ultrasounds from the anthropometric point of view, considering the connected Sub-criteria;
* *Cognitive ergonomics*: allows a less risky and more comfortable performing ultrasounds from a cognitive point of view, considering the connected Sub-criteria;
* *Work environment*: allows a less risky and more comfortable stay in the work environment, considering the connected Sub-criteria;
* *Work management*: improves and eases the management of the sonographers’ work activities, considering the connected Sub-criteria;
* *Patient*: allows a simpler interaction sonographer-patient and a more comfortable patient positioning, considering the connected Sub-criteria;
* *Productivity*: increases the number of ultrasounds at the same cost, considering the connected Sub-criteria;
* *Capability*: improves the ability to realise an ultrasound that will fulfil its requirements, considering the connected Sub-criteria;
* *Flexibility*: is more adaptable to different spatial requirements, considering the connected Sub-criteria;
* *Characteristics of the device*: has better quality characteristics, considering the connected Sub-criteria.

# Meanings of the Sub-criteria

* *Efforts and movements*: allows the sonographer more comfortable efforts and movements, considering the connected Sub-sub-criteria;
* *Postures*: improves the posture of the sonographer while performing an ultrasound, considering the connected Sub-sub-criteria;
* *Accessibility and reach zones*: can be used by a larger number of people from a population with the widest range of characteristics to achieve a specified goal in a specified context of use [work area clearance, size of objects, action demand, coordination demand, stability demand (ISO 26800, 2011; ISO 14738, 2002; ISO 11064-4, 2013)];
* *Transducer size*: has dimensions which reduce discomfort, difficulties and limitation for the usage from an anthropometrical point of view [dimensions of transducer, user population, anthropometric data (ISO 15537, 2004; ISO/TR 7250-2, 2010; ISO 7250-3, 2015)];
* *Visual requirement*: allows a better view of visual targets [visual field, angles of view, viewing distance, size of the visual target (ISO 9241-5, 1998; ISO 14738, 2002; ISO 11064-4, 2013)];
* *Easy to understand*: allows better perceptive and cognitive interaction between specified users and information devices to achieve specified goals in a specified context of use [task characteristics, information device characteristics, personal details, skills and knowledge, personal attributes (ISO 9241-11, 1998; ISO/TR 16982, 2002)];
* *Easy to use*: allows better perceptive and cognitive interaction between specified users and command devices to achieve specified goals in a specified context of use [task characteristics, command device characteristics, personal details, skills and knowledge, personal attributes (ISO 9241-11, 1998; ISO/TR 16982, 2002)];
* *Mental stress*: reduces the influences upon a human being from external sources and mental effects on the person [task demands, social and organisational factors, physical conditions, individual characteristics (ISO 10075, 1991; ISO 10075-2, 1996)];
* *Lighting environment*: guarantees a greater visual comfort considering the required work tasks [illuminance and its distribution, luminance and glare, directionality, colour aspects, type of visual work tasks (ISO 8995-1, 2002; EN 12464-1, 2011)];
* *Space demands*: guarantees a greater freedom of movement for a working area of equal size [clearances, dimensions of devices and objects, action demand, possibility for adopting different posture (ISO 14738, 2002; ISO 12100, 2010)];
* *Competence and training*: requires lower training needs associated with its occupational health and safety risks [roles and responsibility, skills and knowledge, awareness, ability, information and training (WHO, 1998; OHSAS 18001, 2007; ISO 13485, 2016)];
* *Work experience*: improves the use of acquired knowledge and experience [years experience, roles and responsibility, skills and knowledge (OHSAS 18001, 2007; ISO 13485, 2016)];
* *Motivation and satisfaction*: guarantees greater pleasure and gratification in the performance of the work task and more positive attitudes towards the use of the device [perceived quality of working life, perceived mental demand, perceived physical demand, worker expectation (OHSAS 18002, 2008; ISO 9241-11, 1998)];
* *Training procedures*: allows for easier establishment, implementation and maintenance of a training procedure [necessary competence, training and awareness (WHO, 1998; OHSAS 18001, 2007; ISO 13485, 2016)];
* *Comfort*: is more comfortable for patients, primarily in terms of position at the beginning of the ultrasound and needs of repositioning, also considering that patients can be totally non-cooperating or partially cooperating [requested position of patient, requested mobility of patient (ISO/TR 12296, 2012; WHO, 2011)];
* *Communication*: allows the sonographer to provide the patient with simpler instructions during the activity/ultrasound [necessary instructions, need for patient interaction (ISO 14155, 2011)];
* *Production capacity*: allows a greater volume of activities/ultrasounds using the current resources [possible number of ultrasounds, feasible ultrasound rate, need for setup or breaks (ISO 9001, 2015)];
* *Costs*: requires a lower initial monetary investment and less fixed and variable costs associated with administering the business on a day-to-day basis [costs of acquisition, operation, user training, support, maintenance (EN 1325, 2014)];
* *Efficiency*: requires less time and other resources to achieve a result/ultrasound [processing time for an ultrasound, auxiliary equipment or materials (ISO 9000, 2015);
* *Effectiveness*: allows a better result/ultrasound in terms of accuracy of diagnoses [behaviour of the medical device in relation to its intended use, quality characteristics of ultrasounds (ISO 9000, 2015; ISO 14155, 2011)];
* *Corporate image*: allows a better sum of impressions and expectations built up in the mind of stakeholders [perceived added value, impact on stakeholders’ perception on the organisation (BS 7000-10, 2008)];
* *Required space*: is less rigid and has fewer requirements if the distribution of space changes [required areas, required facilities and utilities, special installation requirements (EN 15221-4, 2011)];
* *Layout*: puts fewer constraints on the surrounding areas and other workstations if the distribution of space changes [sizes, potential incompatibilities with other activities (EN 15221-4, 2011)];
* *Availability*: increases the ability to be in a state to perform as and when required [electrical system and/or battery reliability, durability, maintainability (EN 13306, 2010)];
* *Resolution*: is able to distinguish two objects at a closer distance [diameter of the ultrasound beam, pulse length (WHO, 2011; ISO 9241-400, 2007)];
* *Quality of service*: provides more robust healthcare services with clinically acceptable level of diagnostic accuracy [signaling speed, maximum turnaround time, data size, disconnect threshold (ISO/IEEE 11073-30300, 2004)].

# Meanings of the Sub-sub-criteria

* *Static strength*: reduces the use of force related to static actions, which are fixed over time and where there is muscle contraction without motion [actual technical actions, static effort, duration and frequency (ISO 9241-5, 1998; ISO/TR 12295, 2014)];
* *Repetitiveness*: reduces the tasks when a sonographer is continuously repeating the same work cycle, technical actions and movements [actual technical actions, frequency, recovery time [ISO 11228-3, 2007; EN 1005-5, 2007; ISO/TR 12295, 2014)];
* *Grip*: allows the sonographer to hold the medical device with more favourable handgrip, i.e. power grip as an alternative to pinch and palmar grip [types of handgrip, duration and frequency, wrist movement [ISO 11228-3, 2007; EN 1005-5, 2007; ISO/TR 12295, 2014)];
* *Applied force*: reduces the physical effort of the sonographer required to perform the technical actions during an ultrasound [actual technical actions, dynamic effort, duration and frequency [ISO 11228-3, 2007; EN 1005-3, 2008; ISO/TR 12295, 2014)];
* *Head and neck*: improves the posture of hand and neck in order to reduce health risks and discomfort while performing an ultrasound [static postures, types and frequencies of movement [ISO 11226, 2000; EN 1005-4, 2008; ISO/TR 12295, 2014)];
* *Upper limbs*: improves the posture of upper limbs in order to reduce health risks and discomfort while performing an ultrasound [static postures, types and frequencies of movement [ISO 11226, 2000; EN 1005-4, 2008; ISO/TR 12295, 2014)];
* *Trunk*: improves the posture of trunk in order to reduce health risks and discomfort while performing an ultrasound [static postures, types and frequencies of movement [ISO 11226, 2000; EN 1005-4, 2008; ISO/TR 12295, 2014)].

# Standards

* BS 7000-10, 2008. Design management systems. Vocabulary of terms used in design management.
* EN 1005-3 (+A1), 2008. Safety of machinery - Human physical performance - Part 3: Recommended force limits for machinery operation.
* EN 1005-4 (+A1), 2008. Safety of machinery - Human physical performance - Part 4: Evaluation of working postures and movements in relation to machinery.
* EN 1005-5, 2007. Safety of machinery - Human physical performance - Part 5: Risk assessment for repetitive handling at high frequency.
* EN 12464-1, 2011. Light and lighting - Lighting of work places - Part 1: Indoor work places.
* EN 1325, 2014. Value Management - Vocabulary - Terms and definitions.
* EN 13306, 2010. Maintenance - Maintenance terminology.
* EN 15221-4, 2011. Facility management - Part 4: Taxonomy, classification and structures in facility management.
* ISO 10075, 1991. Ergonomic principles related to mental work-load - General terms and definitions.
* ISO 10075-2, 1996. Ergonomic principles related to mental workload - Part 2: Design principles.
* ISO 11064-4, 2013. Ergonomic design of control centres -- Part 4: Layout and dimensions of workstations.
* ISO 11226, 2000. Ergonomics - Evaluation of static working postures (including Cor 1:2006).
* ISO 11228-1, 2003. Ergonomics - Manual handling - Part 1: Lifting and carrying.
* ISO 11228-2, 2007. Ergonomics - Manual handling - Part 2: Pushing and pulling.
* ISO 11228-3, 2007. Ergonomics - Manual handling - Part 3: Handling of low loads at high frequency.
* ISO 12100, 2010. Safety of machinery - General principles for design - Risk assessment and risk reduction.
* ISO 13485, 2016. Medical devices - Quality management systems - Requirements for regulatory purposes.
* ISO 14155, 2011. Clinical investigation of medical devices for human subjects - Good clinical practice (including Cor 1:2011).
* ISO 14738, 2002. Safety of machinery - Anthropometric requirements for the design of workstations at machinery (including Cor 1:2003 and Cor 2:2005).
* ISO 15537, 2004. Principles for selecting and using test persons for testing anthropometric aspects of industrial products and designs.
* ISO 7250-3, 2015. Basic human body measurements for technological design - Part 3: Worldwide and regional design ranges for use in product standards.
* ISO 8995-1, 2002. Lighting of work places - Part 1: Indoor (including Cor 1:2005).
* ISO 9000, 2015. Quality management systems - Fundamentals and vocabulary.
* ISO 9001, 2015, Quality management systems - Requirements.
* ISO 9241-11, 1998. Ergonomic requirements for office work with visual display terminals (VDTs) - Part 11: Guidance on usability.
* ISO 9241-5, 1998. Ergonomic requirements for office work with visual display terminals (VDTs) - Part 5: Workstation layout and postural requirements.
* ISO 9241-400, 2007. Ergonomics of human - system interaction - Part 400: Principles and requirements for physical input devices.
* ISO/IEEE 11073-30300, 2004. Health informatics - Point-of-care medical device communication - Part 30300: Transport profile - Infrared wireless.
* ISO/TR 7250-2, 2010. Basic human body measurements for technological design - Part 2: Statistical summaries of body measurements from national populations (including Amd 1:2013).
* ISO/TR 12295, 2014. Ergonomics - Application document for International Standards on manual handling (ISO 11228-1, ISO 11228-2 and ISO 11228-3) and evaluation of static working postures (ISO 11226).
* ISO/TR 12296, 2012. Ergonomics - Manual handling of people in the healthcare sector.
* ISO/TR 16982, 2002. Ergonomics of human-system interaction - Usability methods supporting human-centred design.
* OHSAS 18001, 2007. Occupational health and safety management systems. Requirements.
* OHSAS 18002, 2008. Occupational health and safety management systems. Guidelines for the implementation of OHSAS 18001:2007.
* WHO, 1998. Training in diagnostic ultrasound: essentials, principles, and standards. Technical Report Series 875, World Health Organization.
* WHO, 2011. Manual of Diagnostic Ultrasound. Volume 1, Second Edition, World Health Organization.

# Element evaluation matrices (case study)

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| --- | --- | --- | --- |
| GOAL | ES | PP | Local priorities |
| Ergonomics, health and safety performance (ES) | 1 | 1/5 | 0.16667 |
| Production performance (PP) | 5 | 1 | 0.83333 |

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| --- | --- | --- | --- | --- | --- | --- | --- |
| ERGONOMICS, HEALTH AND SAFETY PERFORMANCE | BI | AN | CE | WE | WM | PA | Local priorities |
| Biomechanics (BI) | 1 | 3 | 5 | 9 | 5 | 5 | 0.44103 |
| Anthropometry (AN) | 1/3 | 1 | 3 | 7 | 3 | 3 | 0.22623 |
| Cognitive ergonomics (CE) | 1/5 | 1/3 | 1 | 5 | 5 | 3 | 0.16157 |
| Work environment (WE) | 1/9 | 1/7 | 1/5 | 1 | 1/3 | 1/3 | 0.02890 |
| Work management (WM) | 1/5 | 1/3 | 1/5 | 3 | 1 | 3 | 0.08275 |
| Patient (PA) | 1/5 | 1/3 | 1/3 | 3 | 1/3 | 1 | 0.05952 |
|  |  |  |  |  |  |  | CR=0.09172 |

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| PRODUCTION PERFORMANCE | PR | CA | FL | CD | Local priorities |
| Productivity (PR) | 1 | 1/7 | 3 | 1/3 | 0.10492 |
| Capability (CA) | 7 | 1 | 7 | 3 | 0.59212 |
| Flexibility (FL) | 1/3 | 1/7 | 1 | 1/5 | 0.05394 |
| Characteristics of the device (CD | 3 | 1/3 | 5 | 1 | 0.24902 |
|  |  |  |  |  | CR=0.05233 |

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| BIOMECHANICS | EM | PO | Local priorities |
| Efforts and movements (EM) | 1 | 5 | 0.83333 |
| Postures (PO) | 1/5 | 1 | 0.16667 |

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| --- | --- | --- | --- | --- |
| ANTHROPOMETRY | AR | TS | VR | Local priorities |
| Accessibility and reach zones (AR) | 1 | 1/7 | 1/3 | 0.08096 |
| Transducer size (TS) | 7 | 1 | 5 | 0.73064 |
| Visual requirement (VR) | 3 | 1/5 | 1 | 0.18839 |
|  |  |  |  | CR=0.06239 |

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| --- | --- | --- | --- | --- |
| COGNITIVE ERGONOMICS | EA | EU | MS | Local priorities |
| Easy to understand (EA) | 1 | 1/7 | 1 | 0.11939 |
| Easy to use (EU) | 7 | 1 | 5 | 0.74705 |
| Mental stress (MS) | 1 | 1/5 | 1 | 0.13356 |
|  |  |  |  | CR=0.01211 |

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| --- | --- | --- | --- |
| WORK ENVIRONMENT | LE | SD | Local priorities |
| Lighting environment (LE) | 1 | 1 | 0.50000 |
| Space demands (SD) | 1 | 1 | 0.50000 |

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| --- | --- | --- | --- | --- | --- |
| WORK MANAGEMENT | CT | WE | MS | TP | Local priorities |
| Competence and training (CT) | 1 | 1 | 1/5 | 5 | 0.19165 |
| Work experience (WE) | 1 | 1 | 1/3 | 3 | 0.17854 |
| Motivation and satisfaction (MS) | 5 | 3 | 1 | 5 | 0.56447 |
| Training procedures (TP) | 1/5 | 1/3 | 1/5 | 1 | 0.06534 |
|  |  |  |  |  | CR=0.08437 |

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| PATIENT | CO | CM | Local priorities |
| Comfort (CO) | 1 | 1 | 0.50000 |
| Communication (CM) | 1 | 1 | 0.50000 |

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| --- | --- | --- | --- |
| PRODUCTIVITY | PC | CO | Local priorities |
| Production capacity (PC) | 1 | 1/5 | 0.16667 |
| Costs (CO) | 5 | 1 | 0.83333 |

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| --- | --- | --- | --- | --- |
| CAPABILITY | EF | EE | CI | Local priorities |
| Efficiency (EF) | 1 | 3 | 7 | 0.64912 |
| Effectiveness (EE) | 1/3 | 1 | 5 | 0.27895 |
| Corporate image (CI) | 1/7 | 1/5 | 1 | 0.07193 |
|  |  |  |  | CR=0.06239 |

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| --- | --- | --- | --- |
| FLEXIBILITY | RS | LA | Local priorities |
| Required space (RS) | 1 | 3 | 0.7500 |
| Layout (LA) | 1/3 | 1 | 0.2500 |

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| --- | --- | --- | --- | --- |
| CHARACTERISTICS OF THE DEVICE | AV | RE | QS | Local priorities |
| Availability (AV) | 1 | 1/7 | 1/7 | 0.06667 |
| Resolution (RE) | 7 | 1 | 1 | 0.46667 |
| Quality of service (QS) | 7 | 1 | 1 | 0.46667 |
|  |  |  |  | CR=0.00000 |

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| --- | --- | --- | --- | --- | --- |
| EFFORTS AND MOVEMENTS | SS | RE | GR | AF | Local priorities |
| Static strength (SS) | 1 | 1/3 | 1/7 | 1/5 | 0.05122 |
| Repetitiveness (RE) | 3 | 1 | 1/7 | 1/3 | 0.09724 |
| Grip (GR) | 7 | 7 | 1 | 5 | 0.64280 |
| Applied force (AF) | 5 | 3 | 1/5 | 1 | 0.20874 |
|  |  |  |  |  | CR=0.09003 |

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| --- | --- | --- | --- | --- |
| POSTURES | HN | UL | TR | Local priorities |
| Head and neck (HN) | 1 | 1/5 | 1/3 | 0.10473 |
| Upper limbs (UL) | 5 | 1 | 3 | 0.63699 |
| Trunk (TR) | 3 | 1/3 | 1 | 0.25828 |
|  |  |  |  | CR=0.03703 |

# Alternative evaluation matrices (case study)

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| --- | --- | --- | --- | --- |
| ACCESSIBILITY AND REACH ZONES | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 5 | 7 | 0.73064 |
| Alternative 2 | 1/5 | 1 | 1/3 | 0.08096 |
| Alternative 3 | 1/7 | 3 | 1 | 0.18839 |
|  |  |  |  | CR=0.06239 |

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| --- | --- | --- | --- | --- |
| TRANSDUCER SIZE | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 1/3 | 1/5 | 0.10473 |
| Alternative 2 | 3 | 1 | 1/3 | 0.25829 |
| Alternative 3 | 5 | 3 | 1 | 0.63699 |
|  |  |  |  | CR=0.03703 |

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| --- | --- | --- | --- | --- |
| VISUAL REQUIREMENT | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 5 | 7 | 0.73064 |
| Alternative 2 | 1/5 | 1 | 3 | 0.18839 |
| Alternative 3 | 1/7 | 1/3 | 1 | 0.08096 |
|  |  |  |  | CR=0.06239 |

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| --- | --- | --- | --- | --- |
| EASY TO UNDERSTAND | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 5 | 0.65864 |
| Alternative 2 | 1/3 | 1 | 1 | 0.18517 |
| Alternative 3 | 1/5 | 1 | 1 | 0.15618 |
|  |  |  |  | CR=0.02795 |

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| --- | --- | --- | --- | --- |
| EASY TO USE | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 7 | 9 | 0.78539 |
| Alternative 2 | 1/7 | 1 | 3 | 0.14882 |
| Alternative 3 | 1/9 | 1/3 | 1 | 0.06579 |
|  |  |  |  | CR=0.07721 |

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| --- | --- | --- | --- | --- |
| MENTAL STRESS | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 5 | 0.63699 |
| Alternative 2 | 1/3 | 1 | 3 | 0.25829 |
| Alternative 3 | 1/5 | 1/3 | 1 | 0.10473 |
|  |  |  |  | CR=0.03703 |

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| --- | --- | --- | --- | --- |
| LIGHTING ENVIRONMENT | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 5 | 5 | 0.71429 |
| Alternative 2 | 1/5 | 1 | 1 | 0.14286 |
| Alternative 3 | 1/5 | 1 | 1 | 0.14286 |
|  |  |  |  | CR=0.00000 |

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| --- | --- | --- | --- | --- |
| SPACE DEMANDS | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 5 | 9 | 0.75140 |
| Alternative 2 | 1/5 | 1 | 3 | 0.17818 |
| Alternative 3 | 1/9 | 1/3 | 1 | 0.07042 |
|  |  |  |  | CR=0.02795 |

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| --- | --- | --- | --- | --- |
| COMPETENCE AND TRAINING | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 5 | 0.63699 |
| Alternative 2 | 1/3 | 1 | 3 | 0.25829 |
| Alternative 3 | 1/5 | 1/3 | 1 | 0.10473 |
|  |  |  |  | CR=0.03703 |

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| --- | --- | --- | --- | --- |
| WORK EXPERIENCE | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 5 | 0.63699 |
| Alternative 2 | 1/3 | 1 | 3 | 0.25829 |
| Alternative 3 | 1/5 | 1/3 | 1 | 0.10473 |
|  |  |  |  | CR=0.03703 |

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| --- | --- | --- | --- | --- |
| MOTIVATION AND SATISFACTION | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 7 | 9 | 0.78539 |
| Alternative 2 | 1/7 | 1 | 3 | 0.14882 |
| Alternative 3 | 1/9 | 1/3 | 1 | 0.06579 |
|  |  |  |  | CR=0.07721 |

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| --- | --- | --- | --- | --- |
| TRAINING PROCEDURE | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 5 | 0.63699 |
| Alternative 2 | 1/3 | 1 | 3 | 0.25829 |
| Alternative 3 | 1/5 | 1/3 | 1 | 0.10473 |
|  |  |  |  | CR=0.03703 |

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| --- | --- | --- | --- | --- |
| COMFORT | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 5 | 7 | 0.73064 |
| Alternative 2 | 1/5 | 1 | 3 | 0.18839 |
| Alternative 3 | 1/7 | 1/3 | 1 | 0.08096 |
|  |  |  |  | CR=0.06239 |

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| --- | --- | --- | --- | --- |
| COMMUNICATION | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 5 | 7 | 0.73064 |
| Alternative 2 | 1/5 | 1 | 3 | 0.18839 |
| Alternative 3 | 1/7 | 1/3 | 1 | 0.08096 |
|  |  |  |  | CR=0.06239 |

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| --- | --- | --- | --- | --- |
| PRODUCTION CAPACITY | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 1/3 | 0.25828 |
| Alternative 2 | 1/3 | 1 | 1/5 | 0.10473 |
| Alternative 3 | 3 | 5 | 1 | 0.63699 |
|  |  |  |  | CR=0.03703 |

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| --- | --- | --- | --- | --- |
| COSTS | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 5 | 0.63699 |
| Alternative 2 | 1/3 | 1 | 3 | 0.25829 |
| Alternative 3 | 1/5 | 1/3 | 1 | 0.10473 |
|  |  |  |  | CR=0.03703 |

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| --- | --- | --- | --- | --- |
| EFFICIENCY | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 1/3 | 0.25828 |
| Alternative 2 | 1/3 | 1 | 1/5 | 0.10473 |
| Alternative 3 | 3 | 5 | 1 | 0.63699 |
|  |  |  |  | CR=0.03703 |

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| --- | --- | --- | --- | --- |
| EFFECTIVENESS | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 5 | 1/3 | 0.27895 |
| Alternative 2 | 1/5 | 1 | 1/7 | 0.07193 |
| Alternative 3 | 3 | 7 | 1 | 0.64912 |
|  |  |  |  | CR=0.06239 |

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| CORPORATE IMAGE | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 1/3 | 0.25828 |
| Alternative 2 | 1/3 | 1 | 1/5 | 0.10473 |
| Alternative 3 | 3 | 5 | 1 | 0.63699 |
|  |  |  |  | CR=0.03703 |

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| REQUIRED SPACE | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 7 | 9 | 0.78539 |
| Alternative 2 | 1/7 | 1 | 3 | 0.14882 |
| Alternative 3 | 1/9 | 1/3 | 1 | 0.06579 |
|  |  |  |  | CR=0.07721 |

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| LAYOUT | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 7 | 9 | 0.78539 |
| Alternative 2 | 1/7 | 1 | 3 | 0.14882 |
| Alternative 3 | 1/9 | 1/3 | 1 | 0.06579 |
|  |  |  |  | CR=0.07721 |

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| AVAILABILITY | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 5 | 5 | 0.71429 |
| Alternative 2 | 1/5 | 1 | 1 | 0.14286 |
| Alternative 3 | 1/5 | 1 | 1 | 0.14286 |
|  |  |  |  | CR=0.00000 |

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| RESOLUTION | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 1/5 | 0.18839 |
| Alternative 2 | 1/3 | 1 | 1/7 | 0.08096 |
| Alternative 3 | 5 | 7 | 1 | 0.73064 |
|  |  |  |  | CR=0.06239 |

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| QUALITY OF SERVICE | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 7 | 3 | 0.64912 |
| Alternative 2 | 1/7 | 1 | 1/5 | 0.07193 |
| Alternative 3 | 1/3 | 5 | 1 | 0.27895 |
|  |  |  |  | CR=0.06239 |

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| STATIC STRENGTH | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 5 | 0.63699 |
| Alternative 2 | 1/3 | 1 | 3 | 0.25829 |
| Alternative 3 | 1/5 | 1/3 | 1 | 0.10473 |
|  |  |  |  | CR=0.03703 |

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| REPETITIVENESS | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 5 | 0.63699 |
| Alternative 2 | 1/3 | 1 | 3 | 0.25829 |
| Alternative 3 | 1/5 | 1/3 | 1 | 0.10473 |
|  |  |  |  | CR=0.03703 |

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| GRIP | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 1/5 | 1/7 | 0.07782 |
| Alternative 2 | 5 | 1 | 1 | 0.43526 |
| Alternative 3 | 7 | 1 | 1 | 0.48692 |
|  |  |  |  | CR=0.01211 |

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| APPLIED FORCE | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 3 | 5 | 0.63699 |
| Alternative 2 | 1/3 | 1 | 3 | 0.25829 |
| Alternative 3 | 1/5 | 1/3 | 1 | 0.10473 |
|  |  |  |  | CR=0.03703 |

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| HEAD AND NECK | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 7 | 9 | 0.78539 |
| Alternative 2 | 1/7 | 1 | 3 | 0.14882 |
| Alternative 3 | 1/9 | 1/3 | 1 | 0.06579 |
|  |  |  |  | CR=0.07721 |

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| UPPER LIMBS | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 7 | 9 | 0.78539 |
| Alternative 2 | 1/7 | 1 | 3 | 0.14882 |
| Alternative 3 | 1/9 | 1/3 | 1 | 0.06579 |
|  |  |  |  | CR=0.07721 |

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| TRUNCK | Alternative 1(Wireless device) | Alternative 2(Portable device) | Alternative 3(Cart-based device) | Local priorities |
| Alternative 1 | 1 | 7 | 9 | 0.78539 |
| Alternative 2 | 1/7 | 1 | 3 | 0.14882 |
| Alternative 3 | 1/9 | 1/3 | 1 | 0.06579 |
|  |  |  |  | CR=0.07721 |