Tipping aid for loading small trucks on waste collection tours

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Tipping aid for loading small trucks on waste collection tours

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Abstract

The global population's continuous growth leads to an escalating production of solid waste. This presents significant challenges, especially in urbanized areas like Zurich. The city's existing infrastructure incorporates recyclable waste collection sites, which are strategically positioned throughout the municipality. Specific workers from the responsible institution manually maintain these sites. This task, which is already physically demanding, is further intensified by the illegal dumping of waste and bulky items by the residents. Despite having vehicles designed for the collection of smaller waste, these workers are often forced to manage large, cumbersome items without appropriate equipment. The severity of the resulting strain is challenging to assess, even though the workers have already reported physical complaints. Therefore, this thesis aims to quantify the strain levels associated with the current activities of the affected individuals. Furthermore, another goal is to develop a technical aid in the form of a concept, specifically tailored to the workers to reduce the physical burden of loading bulky items. To achieve these objectives, scientifically recognized ergonomic risk assessment methods were employed, original studies were conducted in collaboration with the workers, and an adapted development process was implemented. Based on the findings, it was evident that the workers are subjected to significantly increased strain levels, leading to elevated risks of both injuries and chronic illnesses. The handling of bulky items significantly contributed to this strain, but so did the activities related to the management of smaller waste. The development process led to the creation of a suitable design concept that effectively meets the diverse needs of the workers. This design facilitates the loading of bulky items into the vehicle without any intervention from the workers. When compared to existing technical products in the market, the developed concept proved to be the most optimal for the given working environment. This research yielded various insights to formulate actionable recommendations and strategies to improve the workers' health and working conditions in the future. It is also advised to implement these recommendations immediately. Moreover, it is crucial to realize the developed design to evaluate its efficacy in reducing physical strain on workers.

1 Introduction

As the global population continues to expand, there is a corresponding rise in the quantity of solid waste produced, and its composition is more complex than ever before. As of 2012, people around the globe were producing approximately 1.3 billion tons of solid waste every year. Based on current trends, this number is expected to increase to 2.3 billion tons by 2025. For this reason, proper handling of produced municipal waste and the application of helpful waste management systems are crucial components of today's society. Various studies indicate that poor waste management can have a tremendous impact on numerous factors, such as the negative effect on public health, the local and global environment, and the economy (Hoornweg & Bhada-Tata, 2012).

Adding to this global view, the unpredictable rise in urbanization, particularly in developing countries, emerges as another vital factor to consider. This imposes considerable challenges on urban areas, necessitating management strategies that are both socially responsible and ecologically sustainable. Primary difficulties encompass the integration of the waste sector in developing nations, the reduction of consumption in industrialized areas, the efficient management of financial resources, and the enhancement of existing management systems to protect public health while minimizing the negative impact on the environment and climate change (Guerrero et al., 2013; Vergara & Tchobanoglous, 2012).

In response to these ongoing challenges, there is a shift in societal priorities. In the present time, heightened awareness of climate change has led to a societal expectation for waste management that balances economic sustainability with environmental responsibility. Improper waste disposal and substandard management practices have significant consequences, including water and air pollution, land degradation, and the emission of methane and other hazardous substances, all contributing notably to climate change. These adverse effects are often due to unregulated dumping practices, open-air incineration, and reliance on landfills. As a result, there is an increasing demand for proper waste disposal, systematic segregation, and enhanced recycling operations (Abubakar et al., 2022; Kassim, 2012).

While these challenges are faced globally, similar dynamics are evident in local contexts, such as within Switzerland, underscoring the need for a closer examination. Particularly, the situation in Zurich serves as a focal point for this investigation, offering detailed insights into its waste management that provides the broader context of this research.

1.1 Solid Waste Management in Zurich

In recent decades, urban areas have faced an escalating amount of municipal solid waste, challenging both the waste management facilities and the environment. Switzerland ranks among the countries producing the most municipal solid waste per capita, with figures rising from 603 kilograms in 1990 to 729 kilograms in 2014. Studies frequently highlight a direct relationship between the volume of waste produced and individual income levels. This connection suggests that as disposable income rises and living standards improve, there is a tendency towards increased consumption, which results in higher quantities of waste. Despite effective recycling practices and waste disposal strategies in place, the volume of waste generated indicates extensive natural resource consumption, posing a significant challenge for the country (Jaligot & Chenal, 2018). Consequently, Switzerland has strengthened its policies since 1990, adopting an "avoidance, reuse, recycling" strategy that yielded a 53% material recovery rate by 2017. These efforts and approaches have proven beneficial, as they also managed to reduce the environmental burden by cutting greenhouse gas emissions from waste by 35% between 1990 and 2017 (Magazzino et al., 2020).

As previously mentioned, the proper collection and disposal of waste become especially critical in densely populated urban areas like Zurich. Consequently, the city has established a comprehensive waste management infrastructure, dedicated to ensuring proper disposal and recycling throughout the municipality. The entity entrusted with this responsibility is known as "Disposal and Recycling Zurich" (ERZ). Through this established infrastructure, ERZ manages the collection and appropriate processing of household waste, organic materials, and recyclables. Furthermore, the city provides designated recyclables collection sites for disposing of waste such as glass, small metals, liquid oils, and textiles. More than 160 of these waste collection sites are strategically distributed throughout the city, each regularly maintained and emptied. For the disposal of larger, bulky items and special waste, the waste management infrastructure extends beyond the regular collection sites by incorporating two dedicated disposal centers.

Despite the substantial investment and ERZ's dedicated efforts, waste collection sites are occasionally misused by residents, leading to the incorrect disposal of bulky goods and hazardous waste. Waste that does not belong at the collection sites is often illegally dumped and typically left on the ground. In addition to smaller waste, bulky items are deposited at recyclables collection sites, leading to increased costs and resource demands for the company. Illustrations of such situations at waste collection sites are shown in Figure 1.1.

Figure 1.1 Illegally deposited bulky goods and small waste at waste collection sites.

The scenarios presented in Figure 1.1 are not unfamiliar to the company and its employees, yet they are becoming increasingly severe, with an ever-growing amount of waste being illegally dumped. To manage these vast quantities of waste, a specialized team within ERZ is assigned with both collecting the discarded materials and cleaning the waste collection sites. The integration of this group within the company is illustrated in an organizational chart in Figure 1.2.

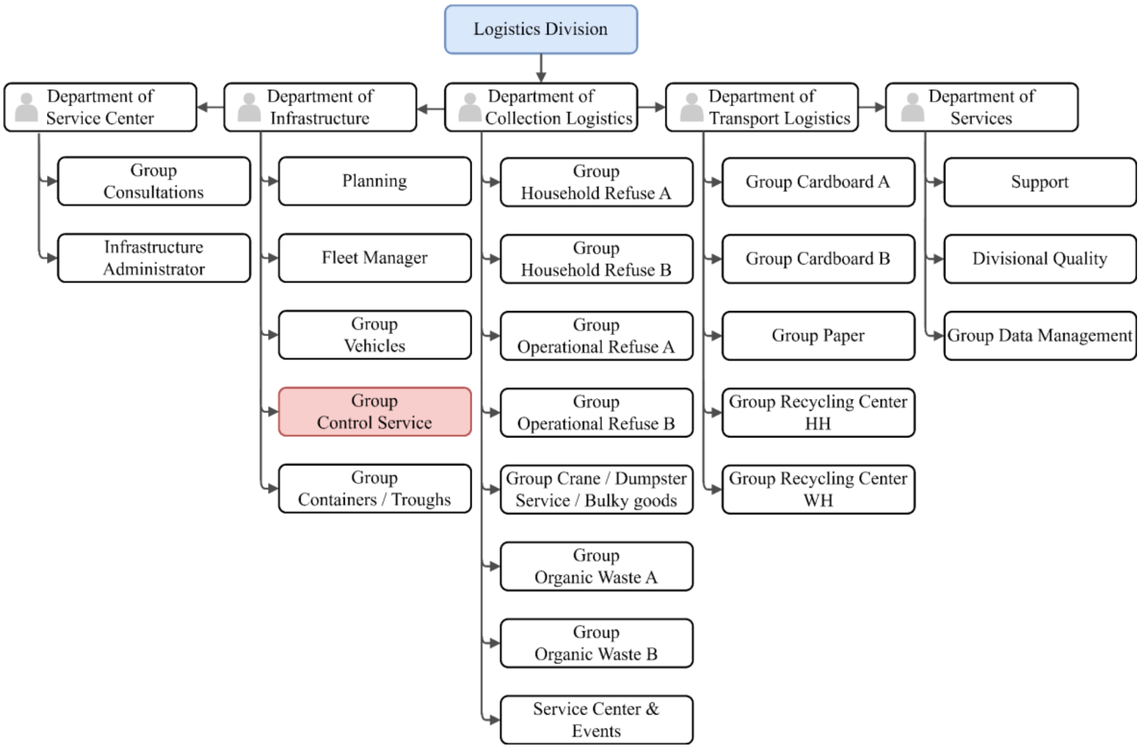

Figure 1.2 Organigram of the logistics division within ERZ.

To manage waste collection effectively, the workers of this group cover specific routes to ensure that all collection sites are serviced. Each tour is consistently assigned to the same employee, enabling them to gain expertise in their designated areas and anticipate the expected quantity of waste. The team, consisting of four individuals, operates specialized trucks designed for small-scale waste collection. It is important to mention that these vehicles are not built for the purpose of loading bulky goods and lack the equipment to facilitate this demanding activity. The workers confront daily pressures to complete their tours efficiently. Complications often arise from improperly disposed of waste, particularly bulky objects, whose size and shape can vary greatly, causing delays and disrupt their routine.

A pivotal principle guides the workers: “Lift everything as long as you do not break your back.” This guideline necessitates that each team member makes instantaneous decisions about their physical capacities regarding the lifting of heavy objects, often leading them into strenuous and potentially hazardous situations. They employ various techniques, including pulling, pushing, tilting, and breaking objects beforehand, to maneuver bulky items into their trucks. Particularly this task frequently results in significant physical strain because of the volume and cumbersome nature of the items. When confronted with excessively bulky items, workers cannot simply ignore it. They must assess whether the situation necessitates calling the bulky waste service for help, a separate division within ERZ responsible for collecting larger items. This call is made only when the on-site waste justifies the additional intervention, resulting in putting the workers in a moral dilemma. Upon finishing their tours or their vehicles reach full capacity, the workers return to the disposal facility. Subsequently, they proceed to unload the vehicle by tipping the entire cargo area of the truck, an action facilitated by built-in hydraulic machinery.

The demands of the job go beyond merely lifting heavy items. Workers also contend with the ergonomics of their vehicles, particularly the loading compartment, which is located above hip level. To overcome this height difference, the workers are forced into uncomfortable and awkward body postures, adding to the physical strain, and posing potential long-term health risks. This aspect, combined with the job’s physical nature and the mental burden of a strict schedule and dealing with improperly disposed of waste, underscores the multiple layers of challenges these employees face every day.

1.2 Manual Material Handling and Musculoskeletal Disorders

Due to the physically demanding activities that the workers manage daily, they are subjected to extreme strains, resulting in a high risk of potential physical complaints and illnesses. Manual labor or manual material handling in their work can lead to severe consequential physical damage, such as the development of musculoskeletal disorders. These encompass various inflammatory and degenerative issues impacting the muscles, tendons, ligaments, joints, peripheral nerves, and blood vessels. Typically, areas like the lower back, neck, shoulders, forearms, and hands are most affected. While these conditions are prevalent globally, significantly affecting individuals' quality of life and incurring considerable costs, they are not exclusively work-related. However, a significant number of all noted or compensable work-associated diseases are indeed musculoskeletal disorders (Punnett & Wegman, 2004).

Studies indicate that elements like posture, exertion, vibration, and repetitive motion are key work-related risk factors contributing to musculoskeletal disorders. All these elements except for the aspect of vibration emerge also in the working conditions of the workers at ERZ. Musculoskeletal disorders may manifest as immediate injuries or as gradual degradation over time. If these conditions persist, they can evolve into chronic issues, potentially resulting in enduring impairments and disabilities (Andrasfay et al., 2021). Additional research conducted in the automotive industry has revealed that most occupational musculoskeletal disorders occur during lifting and lowering tasks, with the lower back being the area most commonly affected by these complaints (Yang et al., 2020). Therefore, it can be inferred that the employees responsible for the waste collection sites in Zurich are at high risk of developing such musculoskeletal disorders unless immediate changes are implemented in their present circumstances.

1.3 Justification and Aims of this Thesis

As highlighted in the previous sections, the proper implementation and application of solid waste management systems within urbanized areas are of great importance in contemporary times. Switzerland, and especially the city of Zurich, faces many challenges in this regard. The focus of this research is placed on the institution ERZ, particularly the workers who are responsible for the waste collection sites and their service. As mentioned before, these individuals are subjected to significant physical strain due to the ever-increasing amounts of waste, which can have severe consequences regarding their health. Specifically, the task of lifting and loading heavy bulky goods presents substantial difficulties for the employees, as the vehicles used are not equipped with the necessary aids for this strenuous activity. An extensive analysis of the working conditions, along with corresponding quantitative data, has not yet been conducted at this point. For this reason, it is essential to investigate and address the factors influencing physical strain more closely to ensure the health and safety of the workers in the future.

The aim of this thesis is to conduct scientific research and assessment concerning the severity of physical strain imposed on the workers. Furthermore, the study seeks to develop a compatible technical aid designed to support them in their daily tasks, thereby reducing physical stress while improving their physical and mental well-being. Consequently, this thesis seeks to answer the following research questions:

- To what extent is the health of the workers endangered and affected by the physical strain imposed through the loading of bulky items into the truck?
- Which technical solutions are promising candidates in terms of efficiency and compatibility with the vehicle, and lead to a reduction of the risk during the lifting and loading task?

In addition, the goal is to provide ERZ with helpful recommendations that can contribute to improving the working conditions. These suggestions aim to outline solution approaches and serve as a solid foundation for effectively implementing the insights gained from this research.

Therefore, the study is crucial for the specific situation of the workers and their health. Additionally, it is also significant concerning the waste management system in Zurich and aims to make it more sustainable within the defined scope. This thesis addresses multiple sustainable development goals, making it multidisciplinary. The pertinent development goals include good health and well-being, responsible consumption and production, and climate action.

The investigations are limited to the workers and their scope of work and only encompass fundamental approaches to improving waste management in Zurich to a certain degree. Nevertheless, certain solution approaches can indeed be adapted and applied to other areas within ERZ. Furthermore, the development of a technical solution encompasses detailed process steps to create a design tailored to the user, meeting the requirements and needs of the workers. Special emphasis is placed on ensuring the compatibility of the technical apparatus with the existing vehicle to design the most optimal and efficient product. Thus, this design can only be utilized for the vehicles in use.

The outlined objectives are to be achieved through the application of scientific methods. The first part of this thesis addresses the health aspects of the workers and their working conditions. To deepen the understanding of the current situation and to capture the crucial requirements of the workers, interviews with the affected individuals are conducted. The investigations and evaluations concerning the severity of the physical strain on the employees is carried out using established ergonomic risk assessment methods. The evaluation is conducted using various methodologies, allowing for the comparison of results based on several approaches. Additionally, practical analyses are undertaken to gather data on the variety and quantities of illegally deposited waste at the waste collection sites. Furthermore, workers are accompanied on their daily tours to identify various physically demanding activities, determine the time required for each task, and observe the techniques and body postures they employ during execution. The observed movements and adopted body postures are visualized and replicated using virtual models. These practical analyses provide essential information and insights and serve as a foundation for the ergonomic risk assessment methods.

The second part of this research involves the execution and documentation of a user-centered design process to develop a beneficial technical solution. The development process is specifically tailored and adapted to the objectives of this thesis. Each step is detailed to capture both the insights gained and the thought processes involved. The process includes phases such as user and the product understanding, concept development, system-level design, and finally, the detailed design. To ensure compatibility of the developed design with the vehicle in use, a virtual model of the truck is created, and the final concept is integrated into it. Ultimately, the developed design concept is compared and evaluated against existing products in the market. To conclude this thesis, helpful recommendations and solutions are presented to ERZ, which incorporate the generated results and gained insights concerning the existing strain on the workers and the developed technical concept.

2 Methods

This chapter provides an overview of the techniques, methods and processes employed during the realization of this thesis, giving more insight to the practical and analytical approaches taken. The following sections describe the applied methodologies in detail, explaining their importance and their application to the scope of this thesis. This chapter lays the foundation for a clear comprehension of the overall performance of this work.

2.1 Ergonomic Risk Assessment

To accurately assess the severity of the physical and mental strain associated with manual labor, various methods and approaches have been envisioned to evaluate the problem and its influences from as many diverse perspectives as possible. Given that this issue represents a specifically applied problem and only affects certain groups of individuals, it has been deemed essential to work closely and collaboratively with the affected parties.

2.1.1 Interviews

At the onset of the project, the analysis of the current situation and circumstances the workers face was deemed crucial to gain a deeper understanding. To qualitatively assess the problem, personal interviews were realized with the affected employees. The individuals possess years of experience, and hence, valuable knowledge and understanding regarding the daily challenges they face. Since they act as experts in this domain, it was essential to extract their inputs, handling, and assessments. Particularly their handling of the problem, how they cope with it and what could be improved were the focus of the organized interviews. The evaluation of the collected information was intended not only to serve as a gain and enrichment towards understanding the existing issues, but also to act as a foundation for the requirements and needs of the subsequent development process of the solution-oriented concepts.

To capture as much information and statements as possible, individual interviews were conducted with all affected users, since the perspectives, impressions, and approaches of the participants regarding a single issue often differ from one another. Each participant was solicited individually on a distinct weekday for the interview to mitigate the potential for mutual influence in their responses and opinions. Additionally, with the consent of the participants, the conversations were recorded to avoid loss of information. The structuring of the guiding questions for the interviews are presented in Appendix A.1.1.

2.1.2 Data collection

The workday of the affected employees often encompasses a diverse range of tasks and activities. Therefore, an accurate ergonomic assessment of the strain experienced can only be conducted when sufficient information regarding the organization and procedures of the work is available. In addition to the qualitative interviews, practical methods were developed to gather quantitative data on the ergonomic strain. These methods are described in the upcoming sub-sections.

2.1.2.1 Time-Motion Study

Accurate assessment of the strain of manual lifting tasks of heavy objects performed throughout the day requires considering the overall strain. A time-motion study helps quantify the work methods, assess their volume, and understand the overall problematics. No previous studies nor data on a workday of affected employees exist. Therefore, conducting such an analysis is crucial for this work. The performed study entailed documenting and observing each physically demanding activity undertaken by a worker during their workday, and measuring the respective time required for the execution of each activity.

To ascertain the various physically demanding tasks, the author of this thesis accompanied one of the workers for a joint workday to experience the tasks and strains firsthand. This experience yielded the necessary knowledge to compile a document of all the relevant assignments a worker must perform at each waste collection site. An overview of the measured activities is depicted in Table 2.1.

Table 2.1 Overview of measured activities.

Parking	Climbing inside of truck and empty waste bag
Opening trunk	Mobbing ground with a broom
Collecting and loading of small trash	Closing trunk
Slit-Container: Emptying	Pulling of heavy objects
Slit-Container: Replacing	Pushing of heavy objects
Recycling	Lifting heavy objects
Cleaning ground	Tilting heavy objects
Cleaning oil station	Securing heavy objects

Subsequently, the study was executed. The designated worker was accompanied throughout the measurement period, wherein the role of the author of this thesis was solely that of an observer and recorder. The time taken by the employee for each task presented in Table 2.1 was recorded with one-second accuracy utilizing a stopwatch. The measurements were documented in the prepared datasheet. In cases where the loading of bulky goods or larger objects was necessary, the types of items in question were documented. In instances where a task was repeated multiple times at one waste collection site, all timestamps for that task were recorded and subsequently summed up for analysis.

The goal of this study was to estimate the amount of time required for each respective task and observe methodologies employed in their execution. The results are intended to serve as a foundation for subsequent risk assessment methods, but also to highlight which tasks are the most time-consuming. Therefore, the generated findings provide useful approaches for the formulation of requirements for the product development.

2.1.2.2 Waste Disposal Analysis

Similar to the time-motion study, a quantitative method was employed to more comprehensively assess the physical strain. This analysis focused on the manually lifted loads by the workers during their daily tasks. The objective was to measure the amount of waste and estimate its potential impact on their health. Additionally, an investigation was conducted to determine whether and how the various days of the week influence the amounts of waste.

The information about the total weight of improperly disposed waste was recorded for the same measurement period as in the time-motion study. There was no possibility of measuring the weight of the bulky waste only, therefore, the total weight of collected waste was recorded. Once the transport vehicle had reached its maximum capacity, it was driven to the company's headquarters. The combined total weight of the vehicle and the waste was measured. Following the automated unloading of the carried waste, the tare weight of the vehicle was measured again. The difference between the two values yielded the total weight of collected waste. On certain weekdays, multiple measurements had to be taken, as the total collected waste exceeded the loading capacity of the transport vehicle.

2.1.3 Site selection

Overall, there are 168 waste collection sites in the city of Zurich, serviced by the workers. They are divided by ERZ into four distinct routes, each handled by a single employee exclusively. These routes are visualized in Figure 2.1.

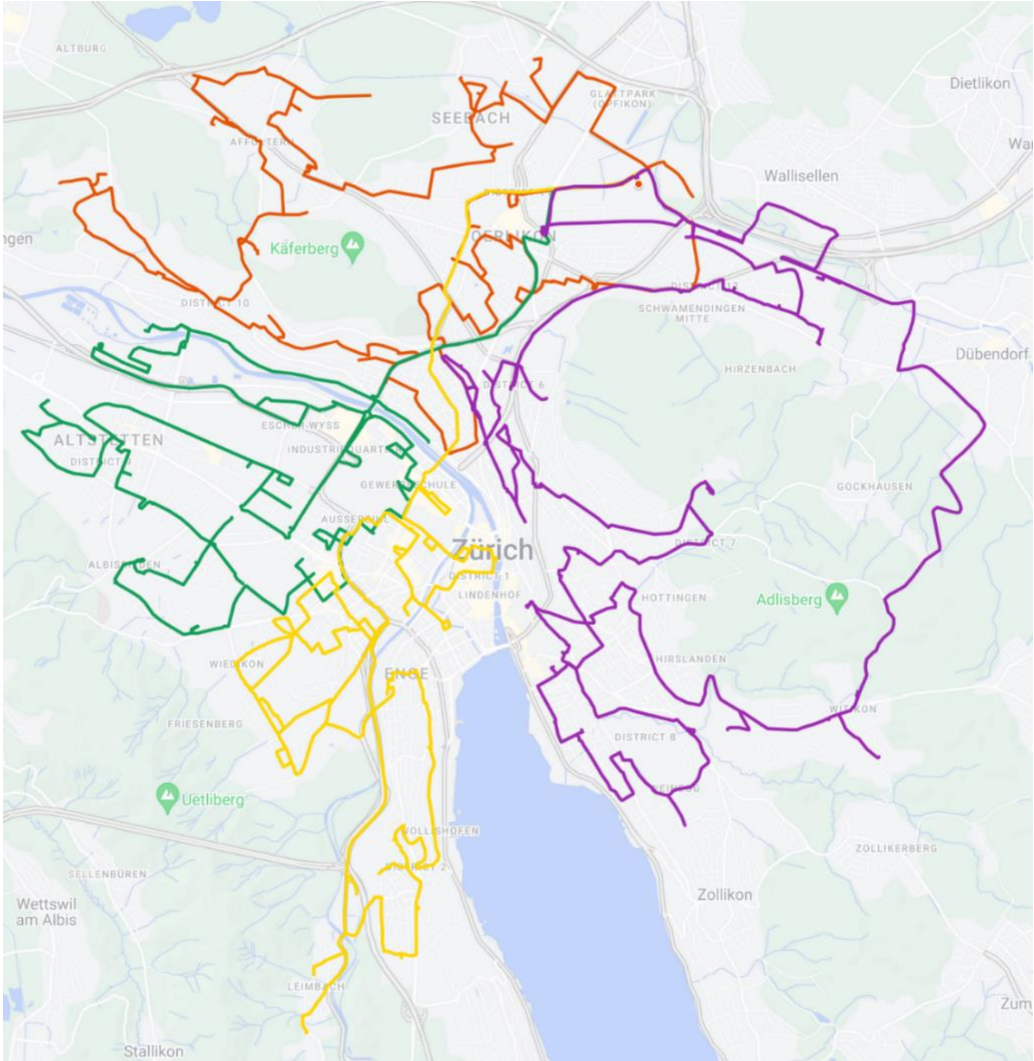

Figure 2.1 Visualization of routes serviced by the workers. Northern route (orange), western route (green), southern route (yellow) and eastern route (purple).

Given that each of the involved employees possesses a distinct working methodology and employs unique techniques to manage daily physical strains, the observations were conducted on various workers to obtain more balanced results. Furthermore, it is highly informative and beneficial concerning the subsequent product development and the objectives of this work, to discern how the working methodologies and the identification of challenges vary from employee to employee. Due to safety and logistical considerations the measurements were taken on two of the four routes.

For the measurement period pertinent to sub-chapters 2.1.2.1 and 2.1.2.2, appropriate existing routes had to be selected that optimally support the objectives of the specified methods. Upon consultation with the employees, the routes delineated in green and orange in Figure 2.1 were selected for the accomplishment of the measurement methodologies, as these encompass the collection sites where, based on experience, a higher incidence of improperly disposed bulky items and substantial waste materials is observed.

2.1.4 Sample Size

Subsequently, the measurement period for the corresponding methods was defined. To design the measurement period as efficiently as possible due to time constraints, while simultaneously minimizing the logistical effort for the affected workers and ERZ, it was determined that each working day should be included to discern any potential influence of the varying weekdays within the data. Therefore, the measurement period spanned a total of ten days, five per route. An average of 42 waste collection sites serviced per day should confirm the proposition that the volume of data generated would be sufficiently large to identify trends and influences.

Regarding the waste disposal analysis, it was perceived as beneficial for the objectives of this work to include additional sources of data. The database of ERZ was used to extract information about seasonal trends of the collected bulky goods and waste for all routes. This approach allowed for more accurate interpretative opportunities concerning the impact of physical strain.

2.1.5 Ergonomic Risk Assessment Methods

To quantitatively evaluate the physical strain from an ergonomic perspective, ergonomic risk assessment methodologies were employed. A distinction is made between the preliminary screening methods, which provide the initial set of results to roughly estimate and evaluate the activity of lifting and loading heavy objects and its effects, and the key indicator method, which enables the evaluation of more complex processes and activities both individually and comparatively, in a more detailed manner. However, since the ergonomic methods could yield differing results when analyzing an identical activity, both types of methods were applied for this work to generate results from as many perspectives as possible. In the following sub-chapters, the methods are described in more detail.

2.1.5.1 Preliminary Screening Methods

In the domain of ergonomic evaluation, it is a common practice to first preliminarily assess and categorize the activity to better estimate the severity of the strain involved. There are several recognized and accepted methods in this field for such assessments. As mentioned in Chapter 2.1.5, using different methods could yield varying outcomes. Hence, three suitable screening methods were selected to evaluate the lifting task of heavy objects and waste materials. The results from all three of them were compared.

Quick Exposure Questionnaire (QEC): This ergonomic methodology evaluates the exposure of the four body areas, specifically the shoulders, back, wrists, and neck, to predominant risk factors associated with work-related musculoskeletal disorders (WMSDs). It has been developed as an observational instrument that engages both practitioners and workers in the assessment process and is applicable to a wide range of physical activities (David et al., 2008).

This method proved to be particularly suitable for this work as it incorporates the involved worker and their assessments into the evaluation process, thereby enabling the utilization and preservation of the employees' experiences.

The Quick Exposure Questionnaire was completed individually with each of the four impacted workers, wherein the author of this thesis assumed the role of the practitioner. It is important to note that exclusively the activity of lifting and loading of bulky goods was evaluated, as this task is the primary motivation for this work and thus its impact should be assessed independently at first. The workers were requested to participate individually to prevent mutual influence of opinions. The role of the practitioner could only be assumed by the author of this thesis because sufficient insights and impressions into the employees' work process were obtained during the measurement period of the conducted analyses mentioned in Chapter 2.1.2. The questionnaire is included in Appendix A.1.2.

Rapid Entire Body Assessment (REBA): This ergonomic method was developed to assess unpredictable and awkward body postures during the execution of physical activities. The technique maintains a balanced equilibrium between the generality of the analysis and the sensitivity of the evaluated activity, implying that it requires fewer and less precise parameters compared to other methods to yield useful results and assessments. It is designed to conduct a sensitive, postural analysis of an activity, wherein the posture can be dynamic, rapidly changing, or even unstable (Hignett & McAtamney, 2000).

This technique was selected due to its simplicity and effectiveness. While more complex and precise measurement methods, such as camera systems or sensors, can offer detailed analysis, the visual observations provided an efficient balance between ease of use and accuracy. The observations of the workers' postures during the measurement period were sufficient to yield reliable results using this approach. As with the Quick Exposure Check, only the task of lifting and loading large and heavy objects was investigated to facilitate a comparison of the final results. The integrated scoring system was used to estimate and categorize the severity of the load. Since the evaluation could be conducted without the participation of the workers, it needed to be carried out only once. The employed paper template of this methodology has been included in Appendix A.1.3.

Rapid Upper Limb Assessment (RULA): This method facilitates an evaluation of musculoskeletal loads in tasks posing a risk to neck and upper-limb loading. It efficiently determines the working posture and the correlated level of risk while necessitating merely a pen and paper for the execution. The RULA scores provide stakeholders or non-ergonomists with evidence to support suggestions that can mitigate musculoskeletal loading. The scores are organized into four action levels, indicating time frames within which risk control measures should be initiated (Hendrick, 2004, pp. 60–70).

Given the strain experienced by the workers' upper body during their daily activities, it was deemed beneficial to incorporate this method into the ergonomic evaluation process. Similarly to the Rapid Entire Body Assessment, this technique is also simple, efficient, and only needs to be conducted once, without the workers' involvement. The paper template used for this method is presented in Appendix A.1.4.

2.1.5.2 Key Indicator Methods (KIM)

The evaluations of the task of lifting and loading heavy, bulky goods using the screening methods were deliberately considered in isolation from other activities, aimed at generating results to obtain a preliminary estimation of the employee's load. However, workers are engaged with many other tasks and activities, negatively impacting their health. Therefore, for the objectives of this work, it was deemed necessary to select and employ an additional method for a more precise analysis of all physically demanding activities. The Key Indicator Methods were specifically designed to evaluate manual handling tasks. They can be categorized into six different subcategories:

- Manual Lifting.
- Holding and carrying of loads.
- Manual pushing and pulling of loads.
- Manual handling operations.
- Whole-body forces.
- Awkward body postures and body movement.

Each type of load has characteristic features such as duration or load weight. Weighting points are assigned to these features depending on their degree of expression. They were redeveloped and updated under the guidance of the German Federal Institute for Occupational Safety and Health (BAuA) and serve as screening tools. It is important though to have a good understanding of the evaluated workstation. These methods help identify areas where the ergonomic design of a workplace can be improved while providing useful suggestions on measures reducing the risks of health issues (Dipl.-Ing. Felix Brandstädt et al., 2019).

For the aims of this thesis, the Key Indicator Methods were selected as a suitable tool. Subsequently, it was necessary to decide which physical activities should be evaluated. All activities of interest are categorized into appropriate Key Indicator Methods:

- **Manual lifting, holding, and carrying of loads:** collecting small waste materials, emptying of slit-containers, lifting of bulky goods and heavy waste.
- **Whole-body forces:** throwing a waste bag into the transport vehicle, manual pushing and pulling of bulky goods.
- **Body movement:** carrying a waste bag over an extended period and distance.

The time-motion study served as a foundation for determining which activities should be assessed using the Key Indicator Method. It facilitated a qualitative estimation of the severity of the respective physical strains, wherein only the critical activities were considered for the following assessment.

Subsequently, the selected tasks were evaluated using interactive forms. The forms utilized can be found in Appendix A.1.5. It is important to mention that the activities were first rated independently. In this assessment method, time weighting played a crucial role in generating accurate results. The data for weighting was extracted from the results of the time-motion study and integrated into the interactive forms. The measured times for the respective activities were averaged over the measurement period.

In a consecutive phase, the activities were collectively evaluated using a distinct interactive form, which can also be found in the Appendix A.1.5. This approach aimed to reveal which activities impose the most severe load on the workers. The features are weighted based on mathematical functions and algorithms, which are illustrated and presented in a separate document (German Federal Institute for Occupational Safety and Health (BAuA), 2020).

2.1.6 Virtual Models

The aim of creating a virtual model was to accurately showcase the movements of the workers as they perform various tasks, to facilitate a visual aid in evaluating the assumed postures and to simplify the implementation of the discussed ergonomic methods. Moreover, these visualizations are meant to help stakeholders understand which types of movements under load are critical and potentially hazardous for the employees. Due to privacy considerations, using snapshots and video recordings were prohibited. To address this issue, a realistic 3D human model was created. This model consists of 15 individual body segments and can be adjusted to assume desired body postures as required.

The construction of the virtual model was facilitated through the utilization of a Computer Aided Design (CAD) software, Onshape (Onshape, 2014). With this model, the accurate representation of critical movement sequences and the range of motion were enabled, significantly simplifying the visualization and identification of awkward body postures during physical demanding activities.

2.2 Product Development & Design

In the following section, the development of a product designed to fulfill the specified requirements and expectations of the users is presented. The importance of a structured approach for this work is explained along with the employed methodologies.

Structured approaches and methods are beneficial for three principal reasons: First, they elucidate the decision-making process, enabling a clearer understanding of the rationale behind decisions among stakeholders and reducing the risk of advancing with unsupported decisions. Subsequently, by providing a specified foundation for key steps in a development activity, they ensure that important considerations and concerns are not overlooked. Lastly, structured methodologies facilitate self-documentation. Through the process of method execution, the user creates a record of the decision-making process for future reference and for educating stakeholders. Although these methods are structured, they are not intended to be applied blindly and without thoughtful considerations. Users are encouraged to adapt and modify the methodologies to better suit their specific needs (Ulrich & Eppinger, 2016).

2.2.1 Development Process

The chosen development process of a suitable lifting and loading aid system is based on the work of Ulrich & Eppinger, (2016) and was supplemented with insightful findings and approaches based on the lecture "Product Development and Engineering Design" by Shea et al., (2022). Given that one of the aims of this thesis is to propose a self-engineered concept of a lifting and loading aid system to the involved company, the development process necessitated appropriate modifications and shortening. For this reason, the subsequent section elucidates the general procedure of the applied development process, followed by further sub-chapters that explain upon the individual methods in greater detail. The adapted process of product development encompasses four distinct phases, as depicted in Figure 2.2.

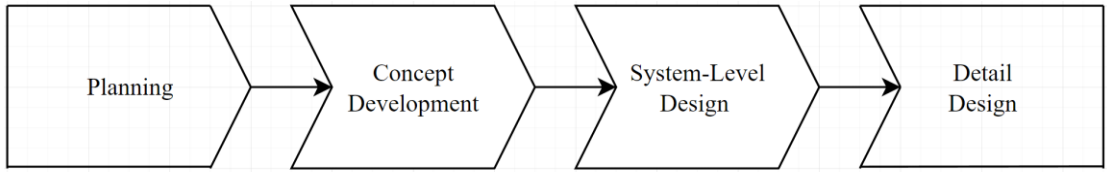

Figure 2.2 Visualization of the adapted product development process.

The planning phase typically begins with identifying opportunities. In this case, the challenging circumstances faced by the affected workers presented a significant opportunity to develop a suitable and beneficial solution. Within this phase, all necessary information is collected to establish a foundation upon which subsequent concept development can be formed. The outputs of the planning phase include the identification of target users, the creation of a user scenario, the mission statement, the formulation of user needs, an activity diagram, the needs-metrics matrix and ultimately setting the target product specifications.

The following concept development phase aims to generate a wide variety of idea proposals and concepts. One perspective on this process entails the initial formulation of a broad array of product concepts, followed by a gradual refinement and enhanced specification of the product. These concepts build upon the fundamental basis established during the preceding planning phase, although they are not defined in detail at this stage. Subsequently, the conceived concepts are evaluated, and the most promising one is selected for further development. It is important to mention that especially this phase is iterative.

The system-level design phase involves defining the product architecture and the decomposition of the product into subsystems and components. In this phase, functional elements of the system are assigned to physical building blocks. The objective of establishing the product architecture is to specify the main physical building blocks of the apparatus regarding their functions and interfaces with the rest of the system. The outputs of this phase include product schematics, a preliminary geometric layout of the product and foundational and incidental interaction graphs.

The detailed design phase is the final stage, and as the name implies, it provides an exhaustive layout of the developed apparatus. Within this phase, insights gathered from the preceding steps are combined. The outcome of this phase is a detailed model that encompasses the final geometry and arrangement of the components.

2.2.1.1 User & Product

In this section, the process phases are elaborated upon and the individually applied methods are described in detail. As an initial step in the planning phase, information regarding the potential users and their situation was compiled in tabular form. This compilation includes information pivotal for the development of a useful apparatus according to the needs of the users and provides a short description of the current state. Subsequently, a target user scenario was composed in story format. It describes the situation of the affected workers in a different manner, thereby providing further insight and clarity regarding how the activity in question is currently conducted, and where and when it takes place. This approach aims to facilitate understanding of the users and their requirements for a useful product and under what conditions they will use the device.

As the subsequent step in this development phase, a mission statement was composed, summarizing the product planning phase. It includes crucial aspects for the product's development such as the product opportunity gap, which aims to highlight the gap between current products on the market and the potential for new or significantly altered ones. Additionally, the mission statement contains the benefit proposition and the key business goals, which are intended to further define the framework and scope of the development process. Moreover, it includes the target market, wherein the main user and secondary users are identified. Lastly, it contains information regarding the assumptions and constraints, along with the associated potential stakeholders.

The aim of the subsequent method is to identify and understand the user needs, and to present them in a clear and organized manner. To gather accurate data, crucial need statements were identified through the conducted interviews with the affected employees, which were then converted into concrete user needs. Subsequently, these were hierarchically categorized into primary and secondary needs based on the type of the need. Afterwards, a relative importance was assigned to the respective needs as accurately as possible, based on the frequency of mentions during the interviews and their relevance to the workers. The output of this process step is a set of carefully constructed user needs, organized in a hierarchical list, with importance weightings assigned to all needs.

An additional procedure within the planning phase encompasses the creation of an activity diagram. This diagram is intended to present and describe the process and manner of product usage, embedding it within the corresponding work environment. It aims to illustrate the entire lifecycle of the apparatus, from procurement to disposal, in a clear graphical representation. This step may also provide the advantage of identifying activities which might not have been considered in previous steps.

At this stage of the planning phase, the introduction of metrics was undertaken. These metrics are precise and measurable quantities, which directly represent the extent to which the product satisfies the user needs. The intention behind these metrics is to transform qualitative user statements into quantitative formulations, thereby translating the critical requirements of the workers into a technical language. This transformation yielded the metrics, with at least one suitable metric being formulated for each user need. The outcome of this method was realized in a needs-metrics matrix and was tabulated for clarity and reference.

The final step in this phase involved assigning and defining appropriate and realistic values to the metrics. Through the addition of values, the metrics are transformed into technical specifications of the apparatus and categorized accordingly. The product specifications provide a precise description of the requisite functions of the product. Targets for these specifications were translated based on the constraints and desires defined by the company and their employees and in conjunction with research and competitive benchmarking. Subsequently, marginal and ideal values were established for each metric, whereby the marginal values should make the product commercially competitive. The output of this method is a tabulated list of target specifications, forming the final foundational element before advancing to the concept development stage.

2.2.1.2 Concept Development

The concept development phase was initiated by the generation of concepts. The aim of concept generation is to explore the spectrum of product concepts that could address the user needs. This phase includes a combination of external search, creative problem solving and systematic investigation of various solutions. Based on the information and insights gathered in the previous phase, many concepts were generated using an adapted version of the brainwriting method for single users, as this method is typically conducted in a group setting. Brainwriting was chosen due to its simplicity and efficiency in generating a diverse range of concepts in a short time and is employed by drawing a conceptual sketch of a specific idea, then shifting focus to a different idea for a few minutes and so on until the first concept is revisited. This procedure was repeated several times with brief rest intervals in between and aimed to mitigate fixation through the consistent exploration of new and varied solutions. The outcome of this activity is an array of concepts. Subsequently, additional variants and designs of the existing concepts were created using heuristic cards, providing an expanded selection of concepts. The heuristic cards yield the benefit of potentially reducing fixation by enabling the transformation of concepts and synthesis of the best parts of multiple concepts (Yilmaz et al., 2015). Before the actual concept selection process, some concepts, which were deemed unrealistic, were already excluded. Subsequently, the remaining illustrations were drawn with greater detail to clarify the intended principles.

After the process of the concept generation, the created conceptualizations were evaluated. Concept selection is an activity wherein various product concepts are analyzed and sequentially eliminated to identify the most promising one. The diverse concepts were all structured within decision matrices. The selection criteria were based on the user needs and product specifications defined in the previous development phase. The method used for the selection process was the Pugh Concept Screening, chosen for its effective yet clear approach. A generated concept was initially selected as a reference and all remaining concepts were evaluated and against it. The concept with the highest rating was selected and the subsequent development process phases were continued with this sole concept.

2.2.1.3 System Level Design

The primary focus of this development phase was to generate the product architecture. This architecture serves as an interface between the functional elements and the physical building blocks of the product. The functional elements can be described as the relevant operations and transformations for the functionality of the device, whereas the physical constituents are parts and components that realize functions of the apparatus. The first step in this phase was the creation of a product schematic to visualize the integrated physical and functional elements. Subsequently, the elements of the product schematic were clustered, a methodological approach of identifying logical groups and reforming them into modules. This procedure aimed to demonstrate simple interactions between modules and help define the design work.

In a following step, a rough geometric layout was created based on the previously defined modules of the system. This layout presents a general arrangement of the components and describe the spatial compatibility and interfaces. The layout is influenced by the technical specifications and geometric constraints of the system. The output of this process was a roughly shaped preliminary design of the apparatus. In the final step of this phase, both fundamental and incidental interaction graphs were created to depict the planned and unplanned interactions among the components. Additionally, these graphical representations are designed to provide the company with comprehensive insights, enabling early identification and comprehension of potential unfavorable interactions and challenges.

2.2.1.4 Detailed Design

In the final phase of the adapted development process, all accumulated data and graphic representations were integrated into a single, detailed design concept. This design was created with Onshape. To ensure compatibility with the transportation vehicle employed by the affected workers, an accurate three-dimensional model of this truck was constructed in the same CAD environment. The creation of this model was achieved based on existing technical drawings and was refined in collaboration with information from the vehicle manufacturing company responsible for modifying and retrofitting the trucks. Subsequently, the finalized design of the potential apparatus was integrated into the model. The result of this concluding step encompasses a detailed design of the developed technical apparatus and an associated model of the transportation vehicle in use.

2.2.2 Concept Evaluation & Recommendation

To provide the company with comprehensive recommendations, technical solutions available on the market were researched and incorporated in addition to the developed design. Subsequently, all technical solutions were comparatively evaluated. The evaluation criteria were not only based on the needs and desires of the workers but also incorporated additional influential factors which might be deemed important by the company, such as the incurred costs or the estimated lifespan of the proposed solutions. Consequently, a tabulated representation of the potential technical solutions was compiled to offer a solid foundation for the company's decision-making process. Moreover, based on the insights, impressions, and experiences accumulated during the execution of this research, additional viable improvement suggestions were formulated to ensure that the company received a broad spectrum of recommendations.

3 Results and Discussion

In this chapter and the subsequent sections, results obtained from the conducted methods are presented. Insights arising from these results are subsequently analyzed and discussed. Consistent with the structure of the previous chapter, the results have been categorized into their respective fields of expertise to maintain clarity.

3.1 Ergonomic Risk Assessment

3.1.1 Interviews

The interviews conducted with the affected workers cannot be published due to data protection considerations, ensuring the privacy and anonymity of the participants. However, this section presents a few remarkable statements in a paraphrased manner, aiming to give a qualitative understanding of the challenging working situation.

"The total amount of waste is getting more and more because the population grows constantly, but the circumstances are not adapted to the employees."

"It does not bother me that I must do this, but it would be nice if it could be a little easier."

"Besides furniture, kitchen and electrical appliances, one encounters just about everything. There is nothing that does not exist."

"Generally everything from the hip upwards hurts after a long day, especially the back and the shoulders."

"The body needs a recovery time, but most of the time it is too short."

"You can still feel the load a few days later."

"The older I get the more physical problems arise."

"A lifting aid could only be an advantage."

"Time, weight, and the unavailability of space are major requirements for a solution."

"The company would support it, especially our boss. He wants to relieve us and helps wherever he can."

"I am on my own on the road."[1]

[1] The paraphrased statements were extracted from the anonymized interviews conducted in German. (*Anonymous interviews with affected employees*, June 2023)

From the statements of the employees, clear insights can be drawn. The affected workers suffer from demanding work conditions, both physically and mentally. If the working conditions do not change soon, the complaints are likely to increase, and the physical strain will impact the workers' health negatively. A technical aid is highly desired, with the company and its leaders fully supporting their employees and eager to alleviate their burdens. However, the requirements for such a solution are complex, and numerous factors play a significant role in it. Such factors include weight, size, ease of handling, deployability, storability, and compliance with road regulations, to name just a few. Further requirements and needs of the workers are elaborated and presented in Chapter 3.2.1.

3.1.2 Time-Motion Study

The results of the time-motion study are presented in Figure 3.1. The Figure shows the summarized durations of all same-category-tasks relative to the total time spent on all tasks. Activities associated with handling heavy and oversized objects are highlighted on the right.

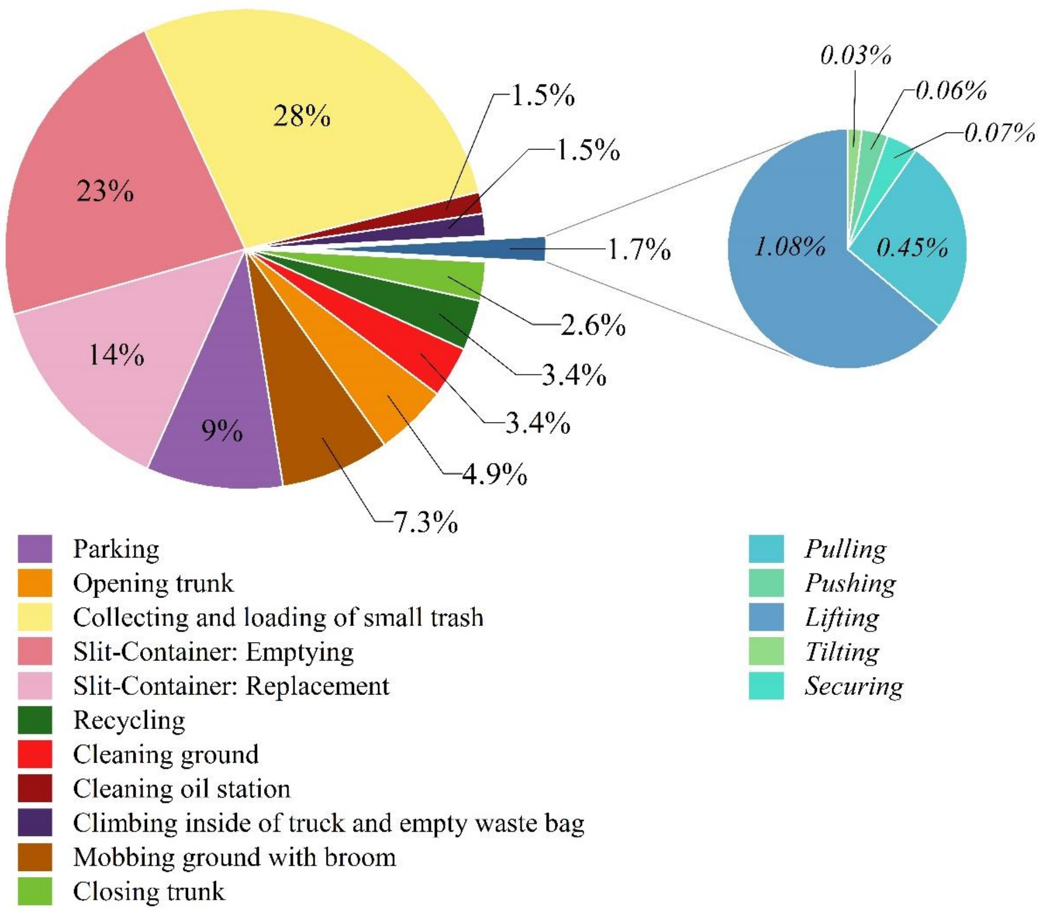

Figure 3.1 Visualization of the results of the time-motion study using a pie chart. The legend on the left is associated with tasks regarding small waste, the legend on the right is associated with tasks regarding bulky items.

Based on the presented results, it is evident that only a small fraction of the time is dedicated to handling bulky objects. The majority of the workers' time is spent on picking up small waste material from the ground and loading it into the transport vehicle. Besides this activity, a significant amount of time is spent emptying and replacing the slit-containers. This is because every waste collection site consistently has at least one of them, making this task the only recurring one at every site.

Even though the time spent on handling bulky goods is minimal, it imposes plenty of strain on the employees. The combination of rapid movements and high forces poses a significant health risk to the workers. A wrong move, an incorrect body posture or a simple slip could lead to serious injuries or even more severe consequences.

From the presented results, significant insights can also be derived for the product development. Given that most of the time is not spent handling heavy goods, it would be counterproductive to develop a solution that would need to be deployed and stowed away at every collection site. Therefore, the technical solution must not negatively affect other tasks or increase the time required for other activities. Additionally, the potential apparatus must not be overly heavy, both to preserve the loading capacity as much as possible and not to increase the frequency with which workers need to return to the headquarters for unloading.

The bulky goods documented during the time-motion study are presented in Table 3.1. An analysis of this data reveals that most of these objects are furniture, followed by electronic devices, all of which were illegally deposited. This emphasizes the necessity for any potential solution to possess the capability to handle a wide variety of objects. To handle the lifting and loading processes of these objects, the workers employed various techniques, such as breaking the furniture to reduce their size and tilting non-destructible items. These techniques and the associated postures adopted by the workers were visually observed, serving as a foundation for the upcoming risk assessment methods.

Table 3.1 List of all the bulky goods collected during the time-motion study.

Wooden Furniture with glass	Wooden chair	Garden chair
Metal bar stool	Carpet (3x)	Bicycle
Grill (2x)	Weight bench	Wooden table
Metal coat rack	Children stroller	Bed frame (2x)
Industrial coffee machine	Umbrella pole out of metal	Umbrella stand with stone base
Printer (3x)	Refrigerator	Large glass pane
Subwoofer (2x)	Wooden cabinet	Mattress
Wooden closet door (2x)	Car wheel rim (7x)	Travel suitcase
Office chair (2x)	Couch	Metal rod

The results presented in this section are extracted from the generated data, which is available within the data repository (Wälti et al., 2023).

3.1.3 Waste Disposal Analysis

In this section, the data related to the weight of the collected waste is presented in the Figure 3.2 and is available within the data repository (Wälti et al., 2023). Based on this illustration, a clear influence of the different days of the week can be observed. The total weight of the collected waste is significantly higher on Monday, roughly three times the value of other days. This distribution can be attributed to the fact that the workers do not service the waste collection sites over the weekend, leading to accumulation of waste. The recorded weights for the other weekdays are relatively consistent, with no noticeable increase towards the end of the week. This pattern is evident over both weeks.

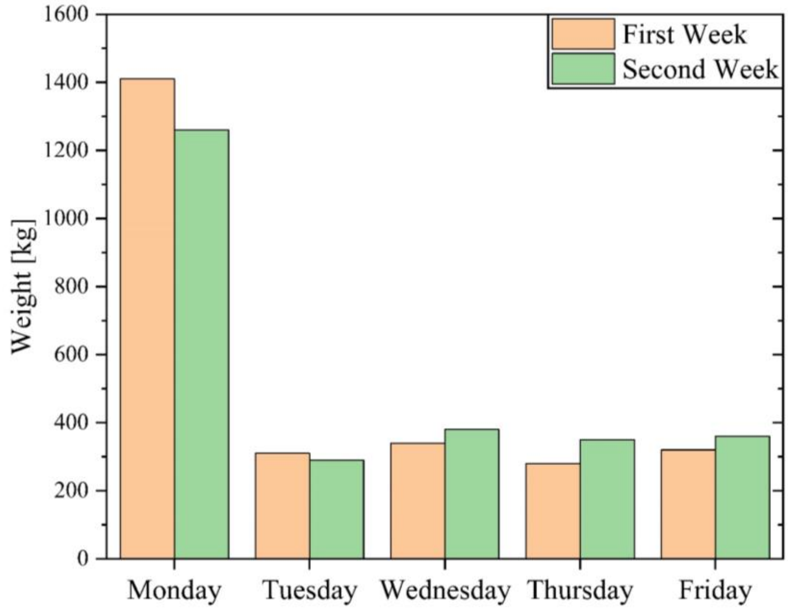

Figure 3.2 Visualization of the measured weights during the measurement period.

Based on this distribution, it can be concluded that Mondays pose the most detrimental physical strain on the affected employees. However, it is not just the physical demands that are increased on this day; the mental health strain is also significantly higher. Workers are required to collect roughly three times the amount of waste within the same timeframe as on other days. If they cannot manage, waste continues to accumulate, leading to the anticipation of the next workday with negative emotions. This time pressure results in elevated stress and can increase the likelihood of injuries among the employees.

Furthermore, the data retrieved from the ERZ database (Disposal and Recycling Zurich, 2022) is analyzed and depicted in Figure 3.3. This dataset encompasses the entire year 2022, incorporating measured data points from each tour serviced by the workers.

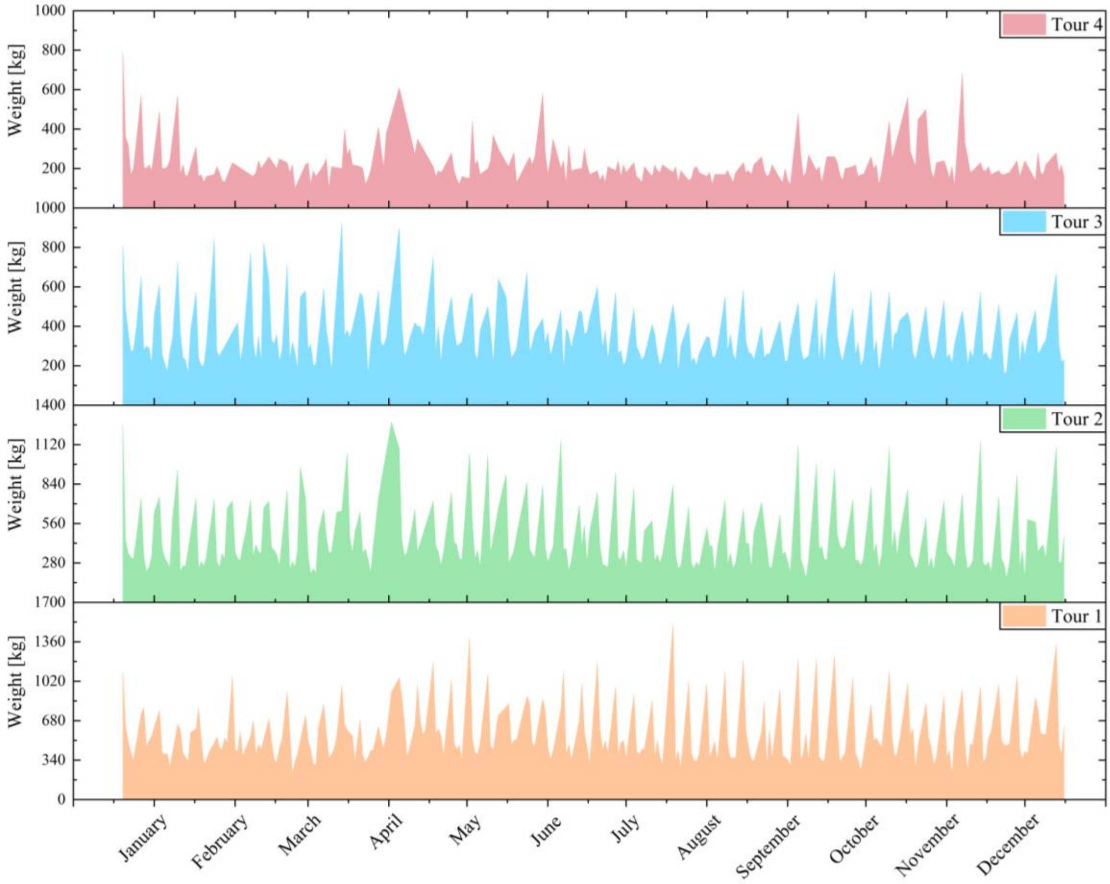

Figure 3.3 Visualization of the data extracted from the ERZ database for the year 2022.

In Figure 3.3, several interesting insights can be observed. In general, it can be asserted that the total quantities of collected waste vary significantly between different tours, implying fluctuating physical demands on the workers for each route. The first tour appears to be the most challenging, whereas the fourth tour seems to be the least demanding in terms of measured weights. Furthermore, there are noticeable seasonal trends. At the beginning of the year, a spike in waste collection can be observed across all tours. This rise might be attributable to the accumulation of waste over the holiday season and people decluttering their spaces for the new year. Another peak around mid-April can be observed in all the tours. This is likely linked to the popular moving dates in Switzerland around the end of March and in April. An increase towards the end of the year can also be noticed, potentially due to similar reasons as at the beginning of the year. It can be assumed that during the time periods where spikes occur, the physical strain on the workers increases proportionally.

Based on the recorded masses alone, it is not possible to evaluate the extent of strain on the workers and whether they are at risk. Qualitatively, it can be argued that an accumulated weight of more than a ton per day is an extremely heavy load for an individual employee to handle on their own. According to guidelines and standards set by recognized organizations, such as the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH), several factors play a crucial role in evaluations and need to be considered in addition to the weight of an object. These factors encompass detailed information about a task, an individual performing it, a load, and the surrounding environment. For this reason, various risk assessment methods were applied, and their results and insights are analyzed and discussed in Chapter 3.1.4 and Chapter 3.1.5.

3.1.4 Preliminary Screening Methods

In this section, the results of the three conducted screening methods are presented, analyzed, and discussed. It is important to note that at this stage, the task of lifting and loading heavy bulky waste is examined to assess the resulting strain of this particular activity in isolation.

Quicke Exposure Questionnaire

The Quick Exposure Questionnaire was filled in collaboration with each affected worker. The outcomes related to the different body areas are presented in Table 3.2 and the results related to other factors are depicted in Table 3.3. The completed templates are available in Appendix A.2.1.

Table 3.2 Results of the conducted Quick Exposure Questionnaire with all the workers related to different body areas.

Participant	Body area	Score	Exposure Level
Worker 1	Back	40	High
	Shoulder/Arm	44	Very High
	Wrist/Hand	30	Moderate
	Neck	6	Low
Worker 2	Back	52	Very High
	Shoulder/Arm	56	Very High
	Wrist/Hand	36	High
	Neck	14	High
Worker 3	Back	40	High
	Shoulder/Arm	44	Very High
	Wrist/Hand	30	Moderate
	Neck	6	Low
Worker 4	Back	40	High
	Shoulder/Arm	44	Very High
	Wrist/Hand	30	Moderate
	Neck	6	Low

The application of the Quick Exposure Questionnaire yields various scores, which are subsequently assigned to an exposure level based on the included scale. This indicates the extent to which the workers are exposed to the strain on the respective body area or factor. For exposure levels labeled as moderate, high, and very high, multiple interactions are likely present. They all need to be identified and limited or adjusted. A high exposure level indicates that injuries to the respective body region are very likely if the activity continues to be performed in the same manner in the future.

The data presented in Table 3.2 reveals that the back, alongside the shoulder and arm regions, are the most heavily affected body areas. The wrist and hand region also show an elevated exposure level, though not as high as the back, shoulders, and arms. This pattern is evident across all participants. The exposure level concerning the neck is rated the lowest for most workers, with one exception. This deviation might be attributed to the diverse techniques the workers employ to manage the activity and the perception of the intensity of the strain being more pronounced for this particular employee.

Table 3.3 Results of the conducted Quick Exposure Questionnaire with all the workers related to different factors.

Participant	Factors	Score	Exposure Level
Worker 1	Driving	4	Moderate
	Vibration	1	Low
	Work pace	1	Low
	Stress	4	Moderate
Worker 2	Driving	4	Moderate
	Vibration	1	Low
	Work pace	4	Moderate
	Stress	1	Low
Worker 3	Driving	4	Moderate
	Vibration	1	Low
	Work pace	4	Moderate
	Stress	4	Moderate
Worker 4	Driving	4	Moderate
	Vibration	1	Low
	Work pace	4	Moderate
	Stress	9	High

The results depicted in Table 3.3 indicate a moderate exposure level related to the factor of driving the transport vehicle for all workers. Similarly, the level concerning work pace is elevated. The assessment of stress is surprisingly not uniform across all participants. For most of the employees this factor is rated moderate to high, whereas one worker perceives the resulting stress as significantly lower. The vibrational influences are rated at the lowest level for all participants, given the absence of any auxiliary equipment usage that could potentially intensify this parameter.

Based on the presented data, it can be concluded that workers are subjected to increased stress levels, predominantly influenced by time pressure. Merely through the activity of handling bulky waste, the body regions above the hip are significantly strained, with the back and shoulder regions being the most adversely affected. The resulting exposure levels reach high to very high ratings, underscoring the urgency for a technical aid and highlighting the risk of potential injuries.

Rapid Entire Body Assessment and Rapid Upper Limb Assessment

The evaluations for both methods were conducted based on the observed postures during the time-motion study. Similar to the Quick Exposure Questionnaire, the resulting scores are evaluated using the integrated rating scale of the respective method. The outcomes of both assessments are presented in Table 3.4. The completed templates can be found in the Appendix Chapter A.2.2 and Chapter A.2.3.

Table 3.4 Results of the conducted REBA and RULA risk assessment methods.

Method	Score	Exposure Level
REBA	12/12	Very High
RULA	7/7	Very High

Based on the results, it can be observed that the maximum possible scores are attained for both methods, indicating that the respective exposure levels reach the highest categorization. This observation further underscores the imperative need to implement changes to protect the health of the workers and improve the prevailing working conditions.

In summary, all three employed screening methods yield similar results and triangulate towards a common insight. The sole task of handling heavy, bulky waste alone induces a significant physical and mental strain on workers, leading to elevated health-associated risks for the employees. The assumption that this activity bears adverse health implications is now supported and substantiated by scientifically validated methods. Nevertheless, the methods applied are simplified techniques to evaluate certain tasks and activities and have their limitations. They offer limited ways to describe the situation being assessed in detail, which is essential for an in-depth analysis and precise evaluation. Only the simplified information can be given about the frequency of task repetition, the weight of the object, and the duration of the task. Furthermore, it is reasonable to assume that other daily tasks of the workers may cumulatively contribute and influence the overall strain. To investigate this assumption in more detail and determine the impact of each physically demanding activity on the overall strain, the Key Indicator Methods were applied. These methodologies and their outcomes are presented and discussed in detail in Chapter 3.1.5.

3.1.5 Key Indicator Methods

In this chapter, the results of the conducted Key Indicator Methods for the selected activities are presented, followed by a discussion of the findings. For a better understanding of the activities and to visualize the body postures of the workers during the tasks' execution, 3D models are displayed for those activities where it is the most critical. The corresponding forms of the employed methods can be found in Appendix A.2.4.

The first activity assessed is the manual lifting and loading of small waste materials. This task involves collecting small waste from the ground and subsequently loading it into a waste bag. The body postures assumed during these movements are depicted in Figure 3.4.

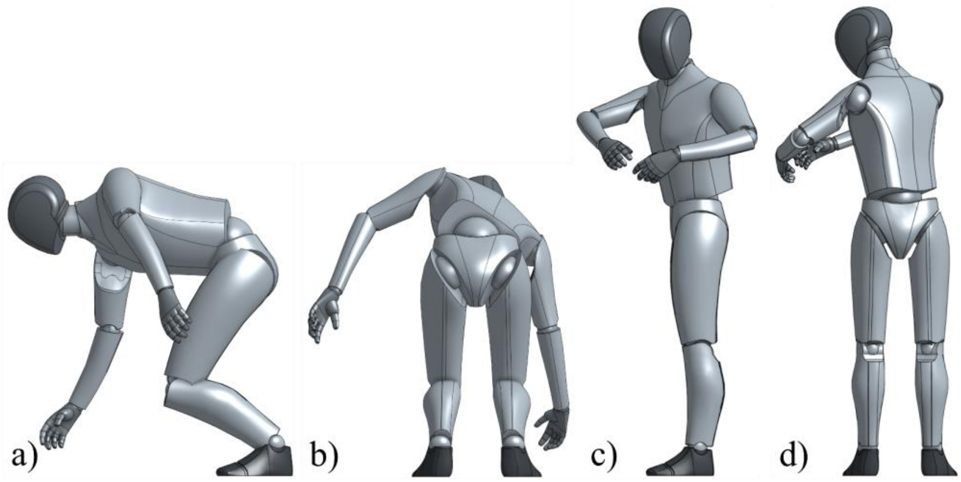

Figure 3.4 Body postures assumed by the workers during collecting and loading of small waste materials. a) Side view of collecting waste, b) Rear view of collecting waste, c) Side view of loading waste into the bag, d) Rear view of loading waste into the bag.

As evident in Figure 3.4, this activity involves bending and extending movements of the upper body, primarily exerting significant strain on the back. Especially during the lifting of small objects but also when loading trash into the waste bag, the back assumes twisted and awkward positions, increasing the physical strain on the body. Due to the frequent repetitions of this task and the constant twisting of the upper body, the health of the workers is severely endangered, and the upper body is subjected to uneven strain which increases the risk of injury.

Another activity encompasses carrying a waste bag over an extended period and distance. As this task is quite self-explanatory, no visualizations were created. The workers typically carry the waste bag in one hand to collect various small pieces of waste on the ground. This task also contributes to the asymmetric loading of the upper body, as the waste bag is usually carried on the same side by the workers. Additionally, as the bag gets fuller and heavier over time, the strain on the respective side of the body increases.

A subsequent activity involves the process of emptying the slit-containers. This task requires workers first to open the container and then extract the full bag. The body postures adopted during this task are illustrated in Figure 3.5.

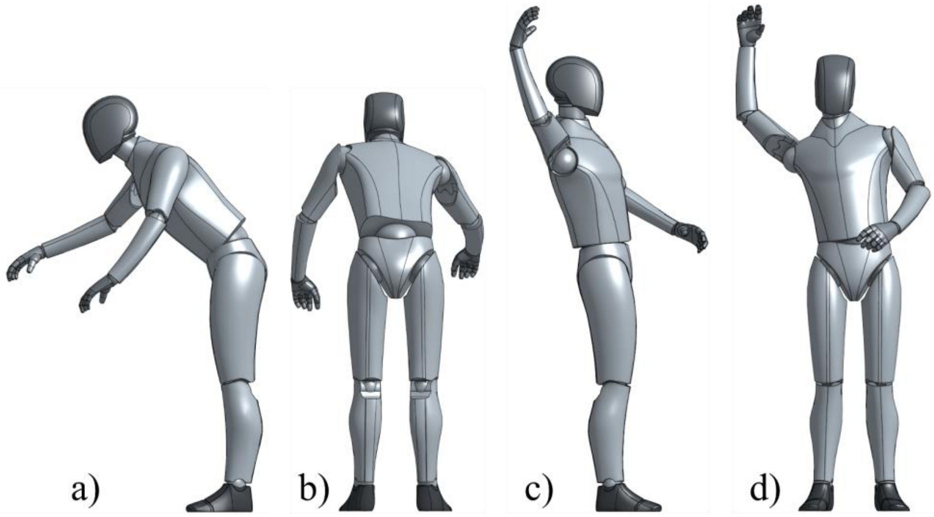

Figure 3.5 Body postures assumed by the workers during the slit-container emptying process. a) Side view of reaching inside the container, b) Rear view of reaching inside the container c) Side view of pulling the bag out, d) Front view of pulling the bag out.

As illustrated in Figure 3.5, workers also assume asymmetrical body postures during this task. When opening the container, workers are compelled to lean forward and use one arm to detach the waste bag from its holder. This action results in a twist of the upper torso and the bending of the back. Subsequently, while removing the bag, employees tear it out of the slit-container, leading to a twist of the upper body in the opposite direction. This motion is highly critical as it is performed relatively quickly, the load is lifted above head height, and the affected regions are not equally strained. As previously mentioned in Chapter 3.1.2, this activity is carried out at least once per waste collection site, making it highly repetitive, which leads to an increased risk of injury.

Subsequently, filled waste bags must be loaded by the workers into the transport vehicle. The body postures assumed during this activity are depicted in Figure 3.6.

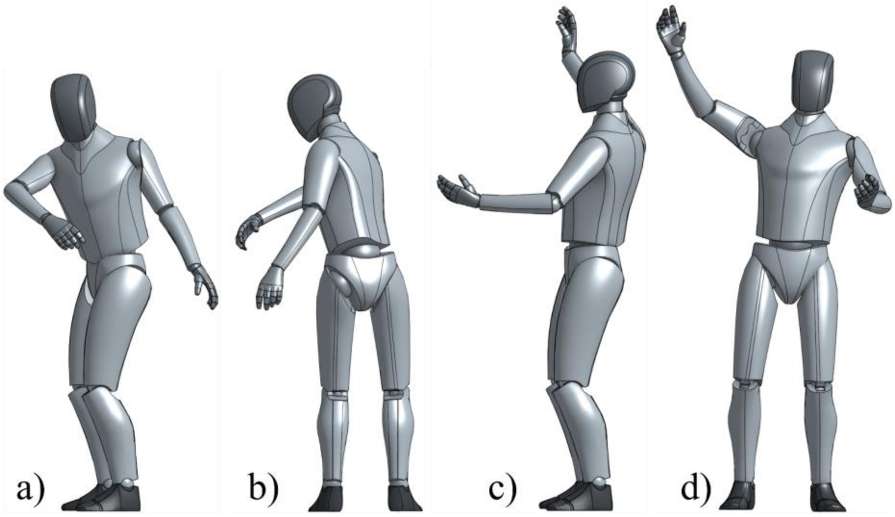

Figure 3.6 Body postures assumed by the workers during the throwing process of a waste bag into the vehicle. a) Side view of aligning the waste bag before throwing, b) Rear view of aligning the waste bag before throwing, c) Side view of the posture after the throw, d) Front view of the posture after the throw.

This activity is qualitatively assessed as one of the more critical based on the observed body postures and the weight of the object. The loading of such a waste bag is dynamic and not performed with controlled movements. Workers must overcome the height of the transport vehicle's deck, significantly above the hip level. The waste bag is not simply lifted, it is thrown. As depicted in Figure 3.6, the bag is positioned before the throw as an initial step. This action is succeeded by a rapid, propulsive throwing motion. The body postures adopted once again show a twisting of the upper body, with significant strain on the lower back and shoulders. This motion also poses a high risk of injury, as the load is thrown uncontrollably and relatively quickly. An asymmetry in the load distribution is also clearly visible in this task.

Next, the activities related to the handling of bulky waste are introduced and presented. The first task addressed involves the manual pushing and pulling of heavy objects. Since most bulky waste items are located away from the waste collection sites, they must first be moved by the workers to the transport vehicle. Depending on the size of these objects, this task requires varying levels of effort, resulting in a fluctuating strain on the body. The body postures adopted during this activity are visualized in Figure 3.7.

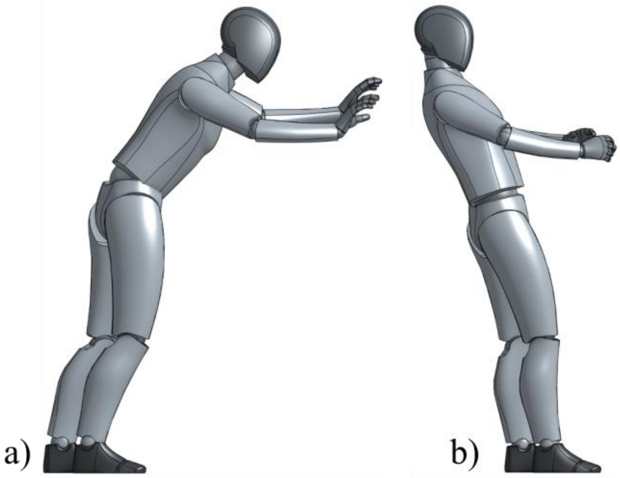

Figure 3.7 Body postures assumed by the workers during pushing and pulling of bulky goods. a) Side view of the posture while pushing, b) Side view of the posture while pulling

As presented in Chapter 3.1.2, workers encounter a wide variety of bulky waste types. Generally, it can be stated that the larger and heavier the bulky waste, the more strenuous the task becomes, leading to the adoption of more awkward body postures. Depending on the type of object, workers must use adapted techniques to transport it as efficiently as possible. The resulting body postures often involve bending of the back and asymmetric loading.

The final assessed task involves the manual loading of bulky goods into the transport vehicle. If workers are unable to reduce the size of heavy objects beforehand, this activity poses one of the greatest threats to employees' health. The body postures assumed during this task are simplified and depicted in Figure 3.8.

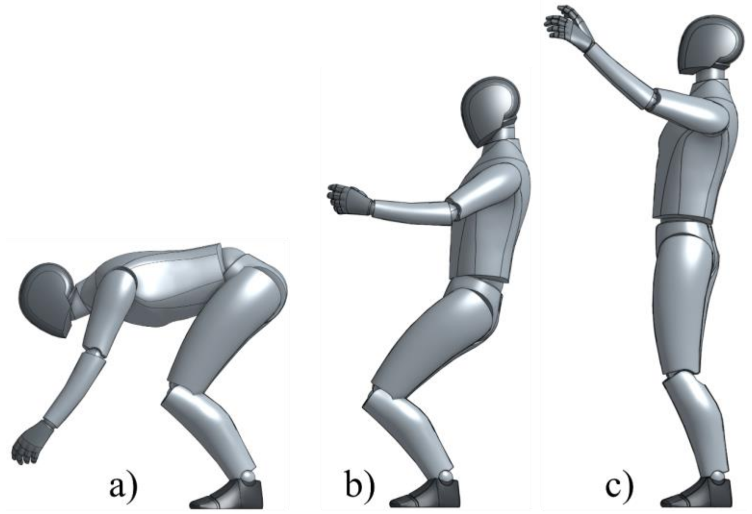

Figure 3.8 Body postures assumed by the workers during the lifting and loading of bulky goods. a) Side view of reaching for heavy goods, b) Side view of lifting the object above the hip, c) Side view after throwing or loading the object into the vehicle.

For this task, it is challenging to present suitable visualizations because the body postures adopted and lifting techniques used by workers vary from object to object. Nonetheless, the illustrations shown in Figure 3.8 should serve as a guide to provide an overview and enhance understanding of this activity. To load bulky waste into the vehicle, workers must again overcome the height of the loading platform. Lifting such heavy objects results in a very high, short-term strain on the back and shoulders, and often involves adopting awkward body postures, leading to an increased health risk. In most cases, the load is also distributed asymmetrically across the upper body.

One of the most demanding movements occurs at the end of this process. Since the vehicle's cargo space is often already filled with smaller waste, it is not sufficient to merely lift the bulky items onto the loading platform. The heavy object must also be raised over the accumulated mound of waste. Consequently, loading typically results in a throwing motion, during which the workers' upper bodies twist, the objects is lifted above head height and immense forces are exerted on their bodies in a short period. The risk of injury during these movements is extremely critical and, depending on the weight of the object, can have serious consequences for the employees' health.

Using the Key Indicator Methods, the evaluation of various tasks performed by the workers results in individual point scores, thus enabling an assessment of the severity of strain through the integrated rating scale. The outcomes of these evaluations are presented in Table 3.5.

Table 3.5 Outcomes and ratings of the conducted Key Indicator Methods.

Task	Key Indicator Method	Score	Load Level
Collecting small waste materials	KIM-LHC	84	Significantly increased
Carrying of waste bags	KIM-BM	42	Moderately increased
Emptying of slit-containers	KIM-LHC	51	Significantly increased
Throwing a waste bag into vehicle	KIM-BF	48	Moderately increased
Pushing and pulling of bulky goods	KIM-BF	28	Moderately increased
Lifting and loading of bulky goods	KIM-LHC	29	Moderately increased

In evaluating the selected activities, it is crucial to understand that these are heavily dependent on time factors and their respective weighting. For each described task, the respective times were extracted from the time-motion study to enable a precise analysis of the strain. Additionally, the scores are categorized into various integrated load levels, where the boundaries are fluid. Therefore, these should be understood as guidance. Fundamentally, it is assumed that with increasing point scores, the likelihood of physical overexertion increases.

Considering the results presented in Table 3.5, all assessed tasks exhibit at least a heightened level of strain, thereby confirming the assumption that the workers are exposed to an increased health risk. It is evident that the activity of collecting smaller waste exerts the highest strain on the body. This finding is reasonable, considering it is the most time-consuming and most frequently repeated of all tasks. The next most strenuous activities are the emptying of slit-containers and the throwing of waste bags into the vehicle, followed by the task of carrying the waste bags. Surprisingly, the handling of heavy bulky waste is at the lower end of the scale. This can be explained by the fact that these activities take little time compared to others, and the resulting strain is correspondingly lower. However, it is remarkable that despite such a short time, the score is relatively high. This insight indicates that even over such a short period of executing the task, the severity of the strain is so significant that it can have health implications for the workers.

In the final stage of this assessment, the selected activities are evaluated in a cumulative manner. This approach aims to identify the types of strain affecting the workers the most detrimentally. This endeavor is facilitated by an additional interactive form that adjusts the scores for an entire workday and compares the different tasks while considering the respective time factors involved.

The extrapolated values resulting from the analysis are depicted in Table 3.7 and the total scores pertaining to each type of physical load are illustrated in Table 3.7. The same integrated rating scale used for the individual assessment of activities is employed.

Table 3.6 Resulting extrapolated scores of the individual activities.

Task	Individual Score	Extrapolated Score for an entire workday
Collecting small waste materials	84.1	288.3
Carrying of waste bags	41.2	216
Emptying of slit-containers	51.8	180.8
Throwing a waste bag into vehicle	49.4	308.7
Pushing and pulling of bulky goods	28.1	288.1
Lifting and loading of bulky goods	29	213.9

Table 3.7 Resulting evaluation of the accumulated activities using Key Indicator Methods.

Physical load type	Total Score	Load Level
Lifting, holding, and carrying	104.1	High
Whole body forces	51.9	Significantly increased
Body movement	41.2	Moderately increased

The presented results indicate that the physical strain from lifting, holding, and carrying objects is by far the most burdensome. This type of strain encompasses not only activities related to handling bulky objects but also managing smaller waste materials. In this context, the task of collecting small waste has the greatest physical impact, followed by the lifting and loading of bulky goods and the emptying process of the slit-containers as depicted in Table 3.6. The total score and the corresponding load level indicate that immediate measures to reduce this type of strain are necessary and is of the utmost priority to protect the workers and their health.

In summary, the methods employed in this assessment quantitatively confirm that workers are subjected to significant physical stress, putting their health at risk. The severity of these strains is represented by various scores, which can be classified using scientifically recognized scales. Based on this analysis, certain activities can be specifically addressed and improved in the future. Surprisingly, it is not the handling of bulky goods that constitutes the most demanding physical activity, but rather the most time-consuming tasks related to dealing with smaller waste. Nonetheless, lifting and loading heavy bulky waste still significantly contributes to the strain experienced by the workers and poses a substantial health risk. The development of a technical solution is intended to eliminate this risk and reduce the likelihood of health impairments. The process of developing an appropriate, helpful solution is explained in detail in the Chapter 3.2.

3.2 Product Development & Design

In this chapter, the various phases of the adapted development process are presented and documented. The illustrations and findings that emerge in this context are displayed, and the insights gained are explained and discussed.

3.2.1 User & Product

In the initial phase of the adapted development process, it is essential to identify and gather information about users and their needs to establish a well-founded basis for subsequent steps in the process. Understanding the given circumstances, the current situation, and the work environment is equally important and crucial for a user-centered development of a suitable product. For this reason, this chapter particularly focuses on the users and their specific demands for a technical product. This approach allows for establishing precise requirements and conditions for the product to ensure that it ultimately provides the desired impact and support the employees urgently need.

3.2.1.1 Target User

The initial stage of the planning phase encompasses information regarding potential users, their needs, and the circumstances in which a technical solution is to be applied to enable a better understanding and clarify important aspects about the existing environment. This approach aims not only to focus on essential factors throughout the subsequent development process but also to provide stakeholders with a fundamental informational basis. The information is presented in Table 3.8.

Table 3.8 Different hypothetical target users.

Question	Target User 1	Target User 2
Who is the user?	Charles, 48yo, manager in a waste collection and disposal company.	Hudson, 55yo, independent manual worker and operator of a small truck.
What do they need?	An affordable device that: • Possesses the capability of assisting or even taking over the lifting task of heavy objects. • Can be efficiently utilized by the user positively impacting their health at work. • Improves the current working environment.	An efficient device that: • Assists with physically demanding tasks. • Can be operated by a single person. • Works fast and is easy to handle. • Improves the current working conditions.
Why do they need it?	The considerable physical strain endured by workers presents a significant concern. This requires the exploration of technological interventions aimed at reducing the likelihood of both accidents and overexertion. The implementation should safeguard workers, enhance operational efficiency, and mitigate potential costs associated with health-related provisions in the event of an accident.	Years of heavy physical labor take a toll on the human body and impact health. To continue work until retirement, the implementation of an assistive tool is a necessity to reduce the physical strain and, consequently, mitigate the risk of health-related injuries.
How is the task currently done?	The workers navigate to the respective collection sites to service them. The workers manually load the entire waste, typically located on the ground, into the transport vehicle. Heavy and voluminous objects are typically subjected to pulling, pushing, and tilting maneuvers to facilitate the loading process. Whenever possible, the objects are shattered and get reduced in size beforehand. Throughout the collection and loading process, the users work alone and wear gloves, safety clothes, and safety footwear.	The user drives to the destination where his work is in demand. Regardless of the nature of the objects involved, they are manually loaded into the user's truck without the use of specific loading techniques. Protective gear is limited to gloves and safety footwear.
Where does it take place?	The collection sites are distributed throughout the city. These sites are situated in open-air environments and are located on asphalt surfaces. Cleaning and unloading of the transport vehicle are normally conducted at the corporate headquarter.	The respective destinations can vary widely, encompassing smaller residential neighborhoods, furniture stores, retail outlets, restaurants, or warehouses as potential operational areas. The user undertakes the cleaning of the truck at their discretion within their own residence.
When does it take place?	The task is repeated multiple times at each collection site. The duration of the task varies depending on the day of the week and the location of the collection site. Several dozen collection sites are serviced on each working day.	The working hours vary according to customer demand and the season. There is generally a higher volume of orders during the moving months. However, assignments are typically processed daily.

3.2.1.2 Target User Scenario

To expand the examination of the current issues and enhance the understanding of the existing situation, a user scenario in a story format is presented in addition to the tabulated information. This scenario includes a description of the problems from the perspective of a fictional user, though it is closely based on real-life circumstances.

Charles is the manager of a small team consisting of 10 employees in a renowned waste collection and disposal company. He leads the team responsible for the cleanliness and maintenance of urban waste collection sites. Beyond administrative and bureaucratic duties, his primary responsibilities include route optimization and allocation of the mentioned collection sites, while concurrently ensuring the physical and mental well-being and efficiency of his team members. He regards the health of his colleagues as the highest priority and continuously aims for its improvement.

At those designated collection sites, waste is often not disposed of in accordance with the city regulations, resulting in most of it ending up on the ground. Besides minor waste, bulky goods are also illegally dumped and must be collected by the workers. The cleaning of these collection sites is conducted manually by the employees without any assistance tools. The small waste is usually picked up from the ground and is subsequently loaded into a compact truck. Given that each worker operates independently on their designated route, the task of manually loading sizable bulky items becomes both laborious and poses potential safety risks. For this reason, employees should utilize a loading aid in the future to assist them in this strenuous task. Upon opening the cargo space of the transport vehicle, the loading aid is positioned accordingly. The apparatus may be located either on the vehicle's undercarriage or attached to the interior surface of the cargo area's ceiling. The positioning process requires minimal manual adjustments, ensuring ergonomic efficiency for the user. The workers then effortlessly load the bulky object into the transport vehicle, without being exposed to any health risks. Upon completion of the loading process, the loading apparatus can be efficiently stowed to ensure unobstructed workflow.

Since the workers are exposed to substantial physical strains, Charles intends to provide them with a tool designed to aid in their daily tasks in the future. This technical solution should assist his employees in the process of loading heavy objects, providing physical and mental relief. Through the utilization of this device, there is an anticipated reduction in accident risk and a consequent enhancement in the efficiency of the operational loading procedure.

3.2.1.3 Mission Statement

In a subsequent stage of the planning phase, the mission statement is presented. It highlights critical factors concerning the product and the characteristics that the solution should ideally possess. Additionally, it provides an overview of the project's scope and contributes to maintaining a focus on the most essential requirements. The mission statement is described in Table 3.9.

Table 3.9 The mission statement for the lifting and loading apparatus.

Product Opportunity Gap	A lightweight device capable of being operated by a single individual. It is cleverly attached to a vehicle in such a manner that it does not obstruct other tasks. The apparatus can be utilized at the user's discretion. It is designed to lift objects of considerable weight and size, irrespective of their nature. It can lift and place them into the cargo area without jeopardizing the user's health.
Benefit Proposition	The design is uniquely adapted to the user and the environmental context. Optimized for an employee's daily tasks, it obviates manual lifting of heavy objects, mitigating both physical and cognitive burdens. The apparatus offers the benefit of functional ease of use while providing psychological relief to the user.
Key Business Goals	The primary objective is to design lightweight apparatus concepts that reduce potential health risks for users. These concepts will provide actionable, innovative recommendations to the organization and are designed to be adaptable to future company needs and demands.
Target Market	**Main user:** Waste collection and disposal company that operates in the city. **Secondary user:** Independent manual workers and private users.
Assumptions and Constraints	• Improvement of existing working conditions. • Lightweight and efficient design. • Operable by a single user. • Functional ease of use. • Size is restricted since available space on the truck is limited.
Stakeholders	• User • City council • Waste collection and disposal company • Communities • Environment

3.2.1.4 User Needs

The acquisition and identification of user needs is one of the most important processes in developing a suitable and helpful product. As previously mentioned in Chapter 2.2.1.1, the statements collected from the workers during the interviews are converted into corresponding needs. In addition to these needs, further important requirements for the product are included in the listing. The generated user needs are presented in Table 3.10.

In total, 25 distinct user needs are identified and classified into appropriate categories, known as primary needs. Each of them is assigned an importance level, intended to reflect the significance of fulfilling that need. For this purpose, a star-rating system is employed, where more stars symbolize higher importance. The assignment of appropriate importance levels is based on the frequency of the need's mention during the interviews and, on the other hand, at the discretion and judgment of the author of this work. Special attention is given to ensure the workers' health and safety attain utmost priority, while also considering the requirements and expectations of the stakeholders.

Table 3.10 The user needs according to statements of the workers and own assessment.

Need	Need Nr.	Ranking
The materials of the device withstand the wear and tear associated with daily use.		
The device exhibits robustness and stability during operation, withstanding substantial forces.	1	*****
The device is shielded against fluid intrusion.	2	****
The materials of the device exhibit resistance to strong cleaning detergents.	3	****
The device is engineered for extended operational longevity.	4	**
The device is resistant to vibrations and external impacts.	5	****
The occupational safety and health of the workforce is ensured.		
The apparatus is securely and efficiently attached to the transport vehicle	6	*****
The apparatus can be operated without necessitating entry into the cargo space.	7	*****
The objects to be loaded are secured during the lifting process.	8	****
The physical and mental strain on the user during the lifting process is minimal.	9	*****
The apparatus supports an efficient operation, loading and unloading process.		
The apparatus possesses the capability to elevate heavy objects irrespective of their nature.	10	*****
The apparatus is capable of loading heavy objects in an acceptable amount of time.	11	***
The apparatus can be operated by a single user.	12	*****
The apparatus possesses the capability to elevate large, unwieldy objects.	13	*****
The apparatus can be operated with minimal manual interventions.	14	***
The apparatus can be deployed with ease.	15	***
The apparatus can be stowed with simplicity.	16	***
During periods of non-utilization, the apparatus does not obstruct other activities.	17	*****
The apparatus does not cause collisions during the unloading process.	18	*****
The apparatus is compatible with the existing transport vehicle.		
The apparatus is built out of lightweight materials.	19	*****
The positioning of the apparatus complies with all regulations set forth by the Swiss Road Traffic Office.	20	*****
The apparatus is located either within the interior of the cargo space or on the undercarriage of the vehicle.	21	*****
The device affords ease of maintenance and repairability.		
Access to the device is unobstructed.	22	**
The device can be easily detached from the transport vehicle.	23	*
The device can be easily cleaned.	24	**
Development and production costs adhere to established financial boundaries.		
The costs of production and assembly are subject to the established boundaries of the company.	25	****

3.2.1.5 Activity Diagram

The next step in this phase involves the activity diagram presented in Figure 3.9. This encompasses the product's lifecycle and its integration into the workers' sequence of activities. The illustration indicates that the apparatus is employed exclusively in instances of existing bulky goods at the waste collection sites.

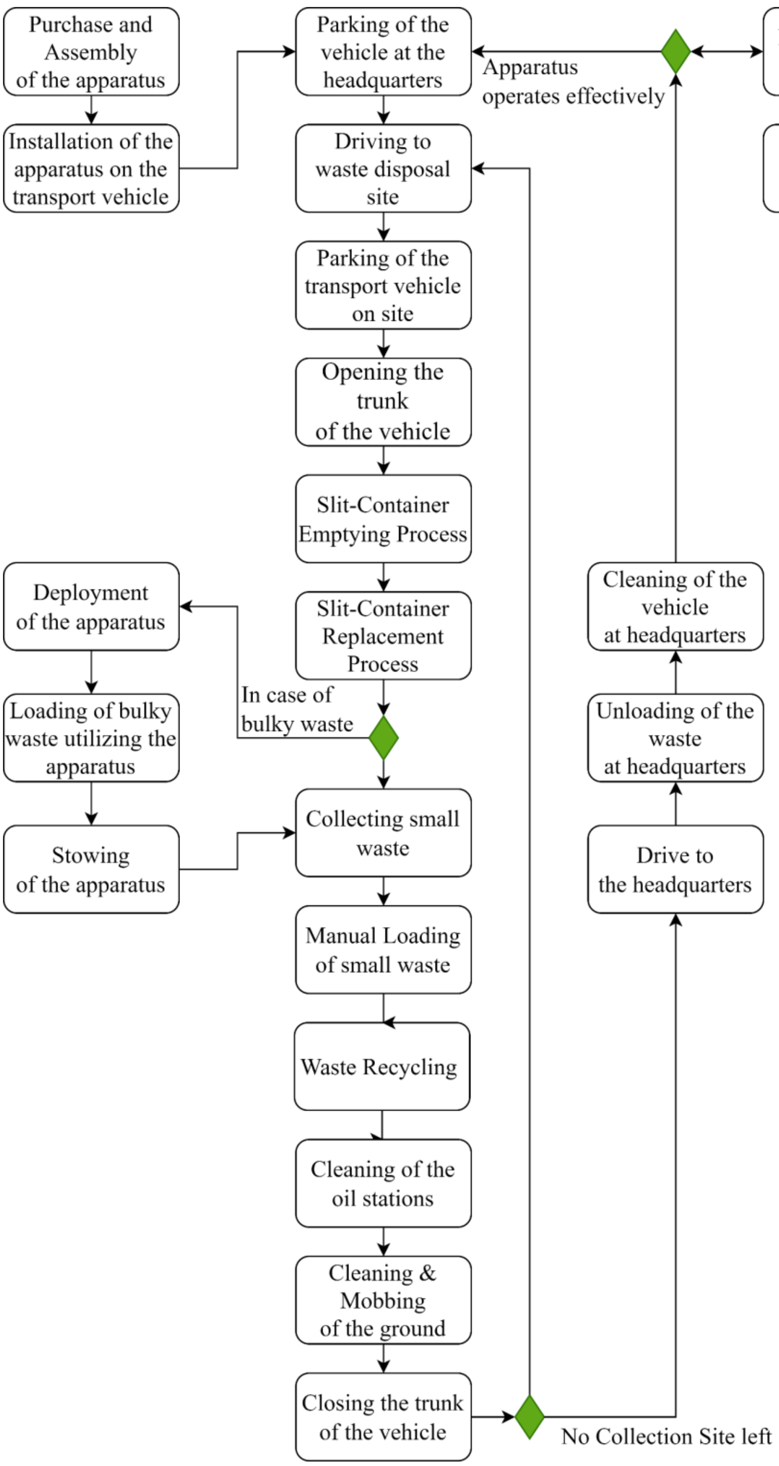

Figure 3.9 Acitivity diagram of the apparatus.

3.2.1.6 Needs-Metrics Matrix

In this step of the planning phase, metrics are introduced. This element is crucial to the adapted development process, as it quantifies the gathered user needs, thereby facilitating useful formulations of the product requirements reflecting the needs and desires of the users. For each need, at least one metric is introduced, translating the qualitative need into technical language. Generally, these metrics possess units and are measurable. The resulting metrics are subsequently depicted in a needs-metrics matrix, visible in Appendix B.1. This illustration clearly delineates which needs correspond to which metrics, thus providing enhanced understanding.

3.2.1.7 Target Product Specifications

Following the creation of the needs-metrics matrix, the corresponding metrics are categorized and assigned appropriate marginal and ideal target values. These are based on the realistic estimations of the author of this work, drawn from research and competitor benchmarking. The resulting categorization and listing are presented in Appendix B.2. It is important to note that assigning appropriate target values to certain metrics can be challenging or technically unfeasible, such as assessing mental well-being during the use of the apparatus or evaluating the workers' safety. Therefore, the assignment of target values also involves subjective assessments.

Since the goal of this work and the adapted product development process is to culminate in a concept proposal for ERZ, the formulations and definitions of target values are of moderate importance, as no physical construction in the form of a prototype takes place. Nonetheless, they are beneficial for the company and the subsequent phases of the development process, as they highlight critical factors that must be considered, thereby serving as guidance for the decision-making and design of a future concept. With the formulation of the target product specifications, the planning phase of the process is completed.

3.2.2 Concept Development

In this section, various concepts are presented, and their intended functionalities explained. Subsequently, the generated concepts are evaluated according to adapted criteria, built upon the foundations created in the previous phase. This approach results in the selection of the most viable concepts, considered essential for a successful user-centered product. This phase of the adapted development process is highly iterative, leading to certain concepts being developed at a later stage than others.

3.2.2.1 Concept Generation

To generate a broad range of diverse concepts, the brainwriting method was adapted and employed. With this technique, rough sketches and illustrations were created, which were further elaborated with heuristic cards. It is important to mention that these concepts underwent an initial sorting before the actual selection process, where those considered unrealistic were already excluded. For illustrative purposes, the remaining concepts were refined. The detailed representations are depicted in this section.

First, the generated concepts concerning the lifting process are presented. These are intended to facilitate the vertical lifting of heavy bulky objects. The corresponding illustrations are depicted in Figure 3.10.

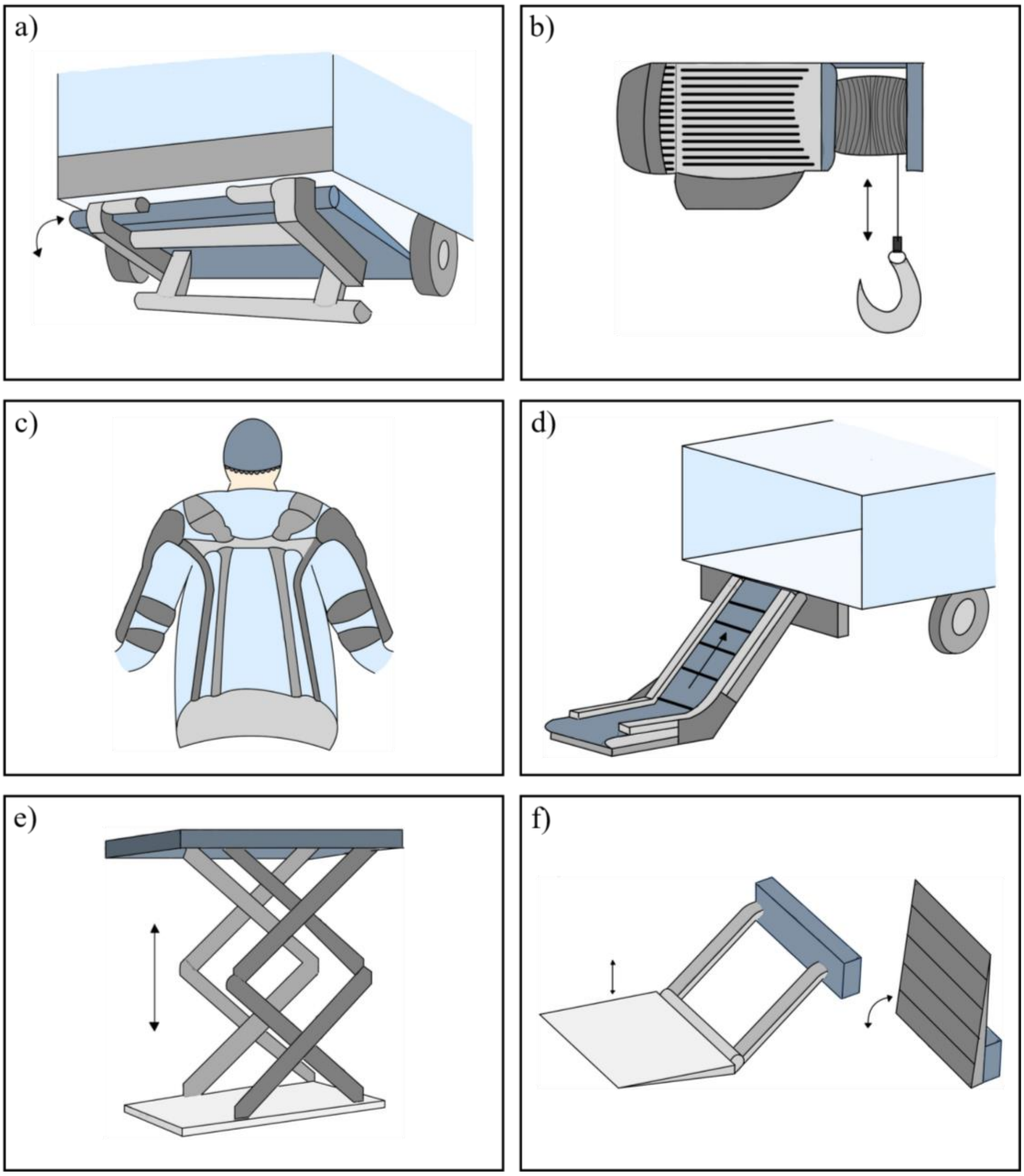

Figure 3.10 Generated concepts regarding the lifting process. a) Stowable tailgate lift, b) Electric chain hoist, c) Exoskeleton, d) Conveyer belt, e) Scissor lift, f) Tailgate lift.

Figure 3.10a shows a concept involving a variant of a lifting platform, designated as a "stowable tailgate lift." Its primary feature allows it to retract beneath the vehicle, negating the necessity for deployment at each waste collection site. Consequently, this design ensures that operations not associated with the handling of bulky waste materials remain unaffected, increasing the efficiency of waste management tasks.

Concept (b) illustrates an electric chain hoist. It features an electrically driven motor responsible for load transmission, a reel on which the chain is wound, and a hook for securing the bulky object during the lifting process. The type and geometry of the hook may vary, allowing for the accommodation of a wide range of objects with different characteristics.

Concept (c) introduces an exoskeleton. This device is worn by the employee over their work attire, aiming to ensure that proper body postures during the lifting process are supported and maintained. Should this exoskeleton be passive, it would be significantly lighter, offering workers more freedom of movement. Nonetheless, the user would need to manage the force transmission themselves. Conversely, an active exoskeleton could not only assist with maintaining proper body postures but also reduce the physical exertion required. However, this comes at the cost of increased weight of the device and restricted mobility of the user.

The concept from Figure 3.10d delineates the utilization of an electrically powered conveyor system. The bulky object is initially positioned on the designated platform and subsequently transported into the vehicle through the mechanized functionalities of the conveyor apparatus. The conveyor system features a rough surface to prevent transported objects from slipping during the lifting process. Additionally, this system is equipped with sufficiently high side edges to prevent the bulky item from falling off laterally.

Concept (e) introduces a scissor lift, which can be propelled either electrically or hydraulically. Through the utilization of a structural truss system, the lifting platform is elevated vertically. This concept also features a rough coating on the loading surface to prevent bulky goods from slipping off.

The final concept (f) eases the lifting process with a conventional tailgate lift. Contrary to the stowable tailgate lift concept, this mechanism is folded at the rear of the vehicle, thereby also functioning as a cover for the loaded waste, preventing the trash from falling out. However, this presents a significant disadvantage because it would need to be deployed at every waste collection site, thereby reducing the general efficiency of waste handling.

Following the vertical lifting mechanisms, concepts for horizontal loading are introduced. After the bulky goods have been elevated, they need to be loaded into the transport vehicle. The generated concepts aim to facilitate this process. The corresponding illustrations are depicted in Figure 3.11.

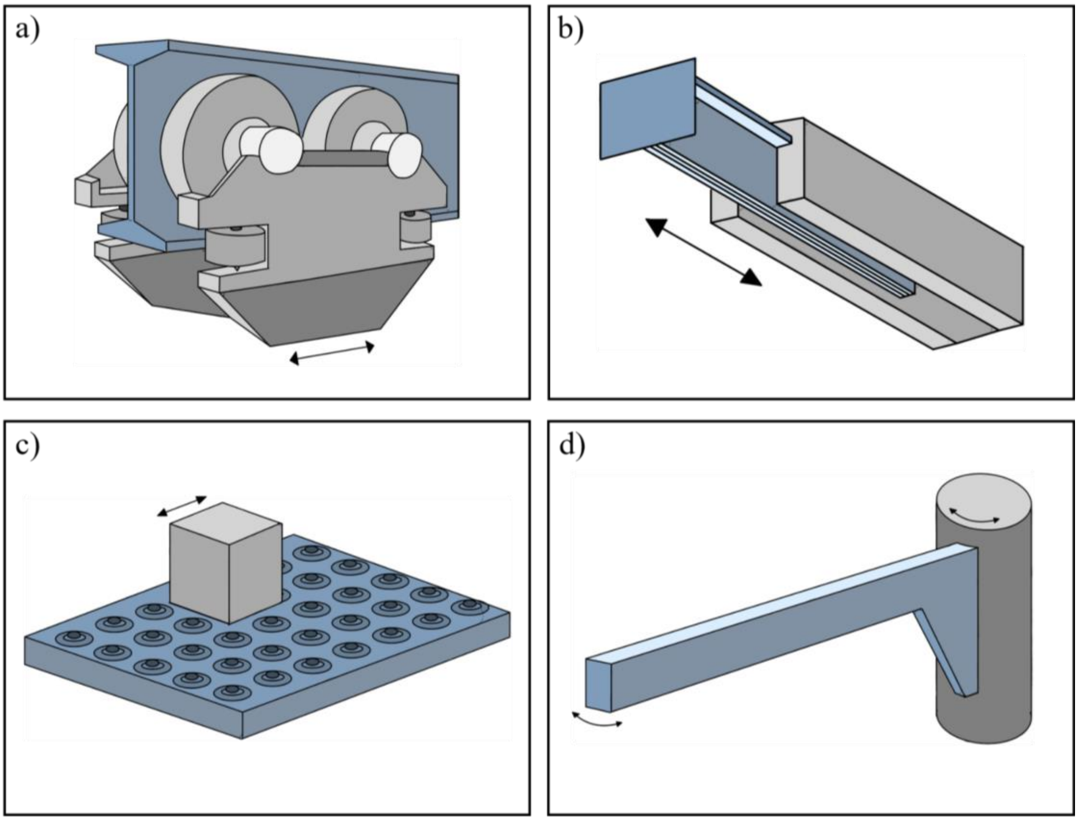

Figure 3.11 Generated concepts regarding the horizontal transfer mechanism. a) Electric beam trolley, b) Shifting beam, c) Ball roller table, d) Swing arm.

The first concept (a) illustrates an electrically powered beam trolley. This device consists of wheels that traverse along a beam or other forms of support, and a housing to which various attachments can be affixed.

The second concept (b) involves interlocking beams, where the outer beam is fixed, and the inner one can move freely along one dimension. The inner beam is situated on rollers, which are propelled by an electric drive mechanism.

The third concept (c) proposes a ball roller table. This consists of numerous ball bearings mounted in a base plate, allowing an object to be traversed horizontally with almost no friction through an initial push.

The final concept (d) presented is characterized by a “swing arm” mechanism. This system incorporates a lever arm which is attached to a pivotable mount and thus facilitates rotational movement.

Lastly, concepts designed to be integrated with the other conceptualizations are presented, serving as attachments to enhance their capabilities. Due to the iterative nature of the process, these were developed at a later stage during the concept development phase. The generated concepts are depicted in Figure 3.12.

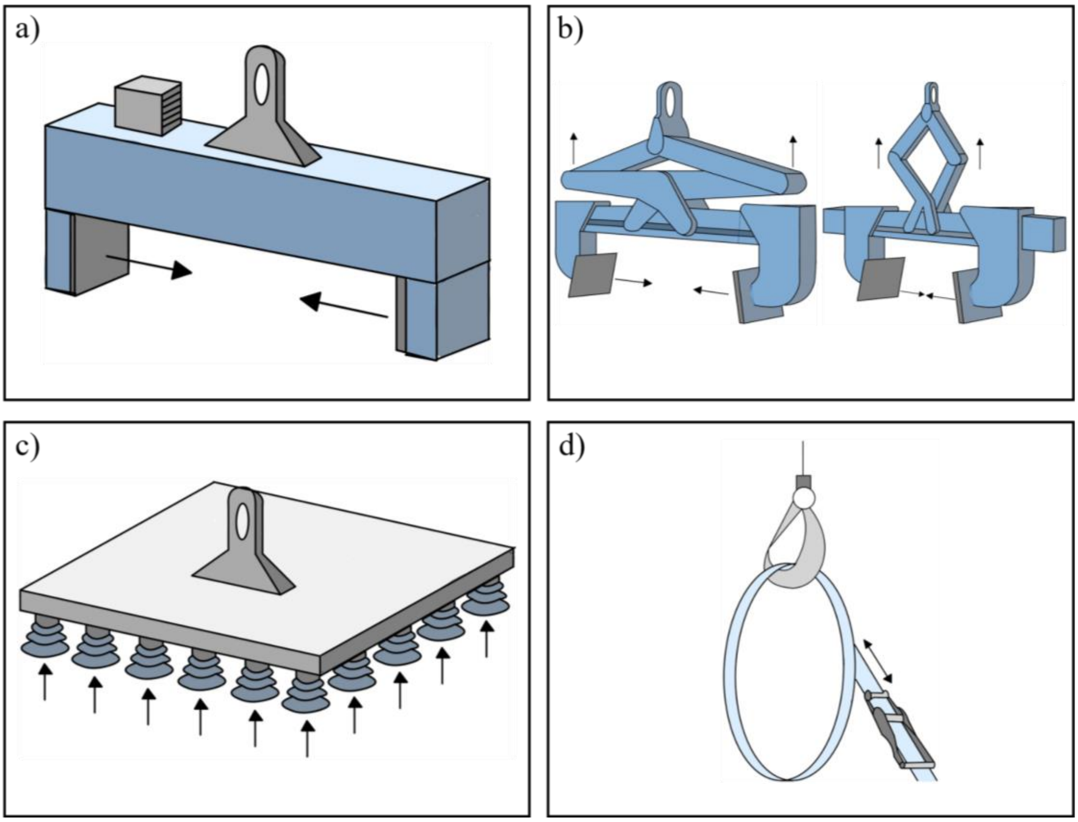

Figure 3.12 Generated concepts regarding lifting attachments. a) Electric clamp, b) Mechanical toggle clamp, c) Vacuum gripper, d) Tension belt with ratchet.

The first concept in Figure 3.12a introduces an electric clamp system, comprising an electrically driven motor and two movable clamps. These are actuated by the motor’s force, thereby facilitating a gripping mechanism for the objects to be loaded.

The second concept (b) also involves a clamp system, though it does not require electric propulsion. The clamping mechanism is purely mechanical. The upper shear beams are equipped with a toggle mechanism and connected to the lower beam, ensuring that the shears automatically open and close with every alternate lifting cycle.

The third concept (c) is a pneumatic system composed of an electric pump and a plate fitted with several suction cups. Through the suction force generated by the pump, larger objects can be attached to the vacuum gripper.

The final concept (d) consists of a tensioning belt coupled with a ratchet mechanism. The bulky item is enveloped by the belt and subsequently tightened using the ratchet, therefore securing the larger object for horizontal transfer.

3.2.2.2 Concept Selection

Subsequent to the step of concept generation, the evaluation and selection of the most promising ideas ensue. This process is conducted with the aid of decision matrices. As previously mentioned in Section 2.2.1.2, the Pugh Concept Screening method is employed for this purpose. The generated conceptualizations are categorized according to their functional application into respective decision matrices. The assessment is based on specific criteria derived from the most crucial user needs and the formulated product specifications. The evaluation and selection of concepts concerning the vertical lifting process are illustrated in Table 3.11.

Table 3.11 Decision matrix regarding the vertical lifting mechanism. Concept A is the stowable tailgate lift, B is the electric chain hoist, C is the exoskeleton, D is the conveyer belt, E is the scissor lift, and Ref is the reference concept of a tailgate lift.

Selection criteria	Concepts					
	A	B	C	D	E	Ref
Ease of handling	0	0	-	+	-	0
Cost	-	+	-	+	+	0
Durability	-	0	-	0	-	0
Accessibility	-	+	+	-	+	0
Complexity	-	+	+	-	+	0
Weight	-	+	+	+	+	0
Modularity	-	+	-	+	+	0
Compatibility with vehicle	-	+	+	-	-	0
Interference with other activities	+	+	+	-	-	0
Safety of user	0	0	-	0	0	0
Loading capacity	0	-	-	-	0	0
Stability during loading	0	-	-	-	0	0
Size	-	+	+	0	+	0
Summary						
Pluses	1	8	6	4	6	0
Sames	4	3	0	3	3	12
Minuses	8	2	7	6	4	0
Net	-7	6	-1	-2	2	0
Rank	6	1	4	5	2	3
Results						
Selection		B				

For the selection of a suitable mechanism to manage the vertical lifting of bulky goods, the concept of the conventional tailgate lift is established as a reference. As indicated in Table 3.11, the evaluation process results in a relatively clear decision to proceed with the concept of the electric chain hoist. This determination is primarily influenced by factors concerning the weight and size of the apparatus, as well as the simplicity of use, cost, compatibility with the existing vehicle, and the attribute that other waste handling tasks are not impeded.

Nonetheless, this concept possesses certain deficits. The loading capacity is lower than that of a standard tailgate lift. However, this is not critical as the requisite capacity is sufficient for most bulky items. Stability may be another challenge, as the bulky items can sway during the lifting process. This aspect needs to be addressed to ensure the workers' safety.

Furthermore, the decision matrix concerning mechanisms for managing horizontal transfers is depicted in Table 3.12. For this assessment, the swing arm concept is established as a reference, and the other concepts are evaluated in relation to it.

Table 3.12 Decision matrix regarding the horizontal transfer mechanism. Concept A is the electric beam trolley, B is the shifting beam, C is the ball roller table, and Ref is the swing arm.

Selection criteria	Concepts			
	A	B	C	Ref
Ease of handling	+	+	-	0
Cost	+	0	+	0
Durability	+	+	+	0
Accessibility	0	+	-	0
Complexity	+	+	+	0
Weight	+	0	+	0
Modularity	+	+	-	0
Compatibility with vehicle	0	0	-	0
Interference with other activities	+	+	-	0
Interference with unloading process	+	+	+	0
Range	+	+	-	0
Size	+	+	+	0
Safety of user	+	+	-	0
Stability during transfer	+	+	-	0
User involvement	+	+	-	0
Summary				
Pluses	13	12	6	0
Sames	2	3	0	15
Minuses	0	0	9	0
Net	13	12	-3	0
Rank	1	2	4	3
Results				
Selection	A	B		

In this selection process, the outcome is considerably less clear. The concepts of the electric beam trolley and the shifting beam score almost equally, making them both promising candidates as potential solutions. The other concepts have a significant lower score in comparison and can therefore be excluded.

To make an informed decision, the challenges of the current work situation are reconsidered. After lifting a bulky object, it needs to be horizontally transferred into the vehicle. To accomplish this operation, the chosen mechanism must be capable of moving both within and outside the vehicle. Despite the electric beam trolley emerging as the superior concept based on the scoring criteria, it cannot independently fulfill this requirement without its components extending beyond the vehicle confines. Consequently, the decision is made to integrate the two highest-rated concepts into a new, unified design and proceed with this solution. This refined approach allows the electric beam trolley to traverse the full extent of the shifting beam, while the shifting beam enables range extension to gain access outside the vehicle.

Following the decisions made for the systems concerning vertical lifting and horizontal transfer mechanisms, additional concepts are developed to provide suitable enhancements, thereby improving the characteristics of the selected concepts. The evaluation and selection of these concepts are depicted in Table 3.13.

Table 3.13 Decision matrix regarding the lifting attachments. Concept A is the electric clamp, B is the mechanical toggle clamp, C is the vacuum gripper, and Ref is the tension belt with ratchet.

Selection criteria	Concepts			
	A	B	C	Ref
Ease of handling	+	+	+	0
Cost	-	-	-	0
Durability	+	+	-	0
Complexity	-	-	-	0
Weight	-	-	-	0
Modularity	+	+	+	0
Compatibility with lifting mechanism	0	0	-	0
Interference with other activities	0	0	0	0
Safety of user	+	+	+	0
User involvement	+	+	+	0
Size	-	-	-	0
Summary				
Pluses	5	5	4	0
Sames	2	2	1	11
Minuses	4	4	6	0
Net	1	1	-2	0
Rank	1	1	4	3
Results				
Selection		B		

For this assessment, the concept of the tensioning belt coupled with a ratchet strap is established as a reference. As depicted in Table 3.13, both clamp systems achieve the highest scores, while the other concepts attain similar ratings. The decisive factors include criteria related to user safety and, most importantly, user involvement. One of the most significant advantages of the clamp systems is that they eliminate the need for workers to climb into the vehicle's cargo area, thereby substantially reducing the risk of injury or accidents. Although these systems have certain drawbacks, such as increased costs, more complex designs, and greater weight and size, their benefits significantly outweigh the negatives. Ease of handling and user safety are particularly crucial in this context and are therefore given a considerable importance.

The decision to select the concept of the mechanical toggle clamp is based on the fact that the other systems are already powered by an electrical drive. This approach avoids unnecessary complication of the overall system, and the purely mechanical operation of the attachment is considered an elegant solution. Ultimately, subsequent process steps will continue with a system comprising the four selected components.

3.2.3 System Level Design

In this chapter, representations and illustrations concerning the product architecture are presented. The selected concepts are intended to be merged in a clear and comprehensible manner, thereby enabling a better understanding of the apparatus. During this phase of the adapted product development process, it is essential to elucidate the interactions of various modules and identify dependencies and potential challenges.

3.2.3.1 Product Schematic

The initial step of this phase involves creating a product schematic that encompasses the functional and physical elements of the apparatus. This schematic is shown in Figure 3.13.

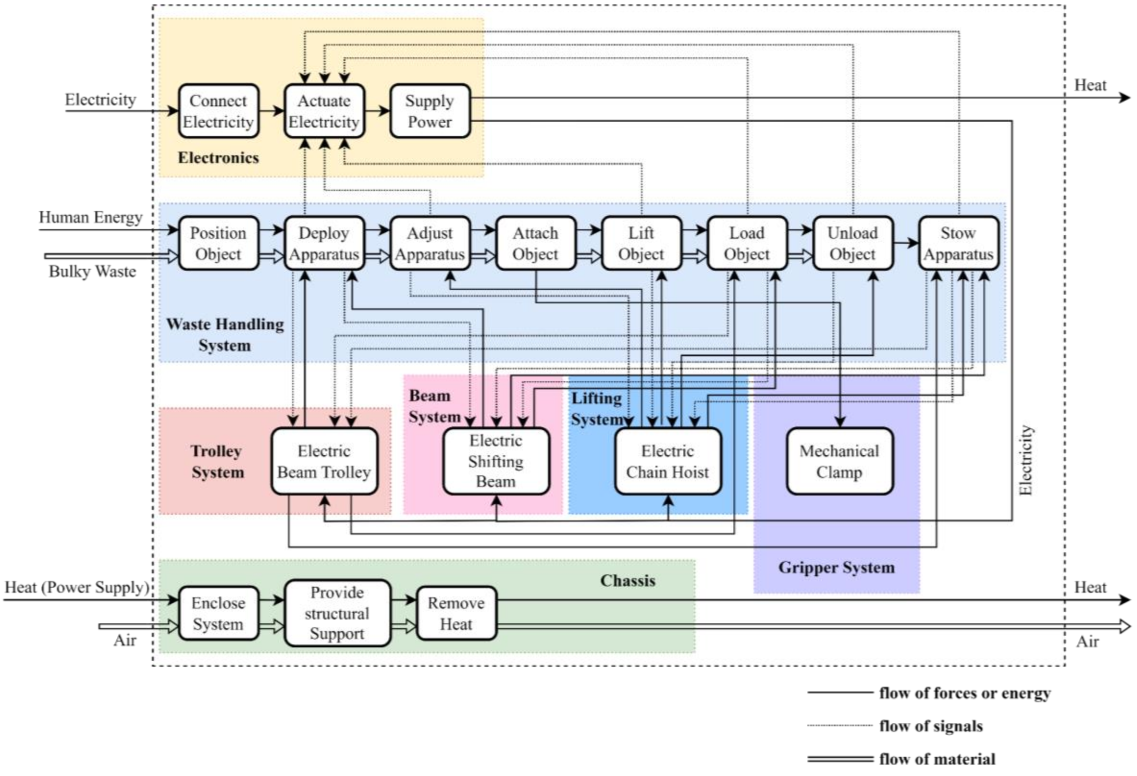

Figure 3.13 Product schematic of the lifting and loading apparatus.

In this representation of the apparatus, the four selected physical concepts are identifiable. Additionally, crucial new modules are integrated and included into the product, designated as electronics, chassis, and waste handling system. The latter describes the sequence of activities that workers employ for handling bulky waste materials. The electronics module is responsible for the power supply of the respective electrically driven concepts. The chassis encloses and protects the product from external influences, provides structural support, and dissipates the heat generated by the motor. The connections between the individual modules illustrate the interactions, energy flows, and flow of signals.

From this illustration, it is evident that the physical concepts are actuated through the initiation of a signal. This signal is triggered by the user. Subsequently, the modules are powered with electricity, which they convert into kinetic energy, enabling the respective module to function as intended. The interaction between the user-initiated signals and the execution by the selected concepts facilitates the lifting and loading process of bulky items.

3.2.3.2 Geometric Layout

The modules are integrated into a rough geometric layout to identify the spatial compatibility of components and define their arrangement. The resulting illustration is presented in Figure 3.14.

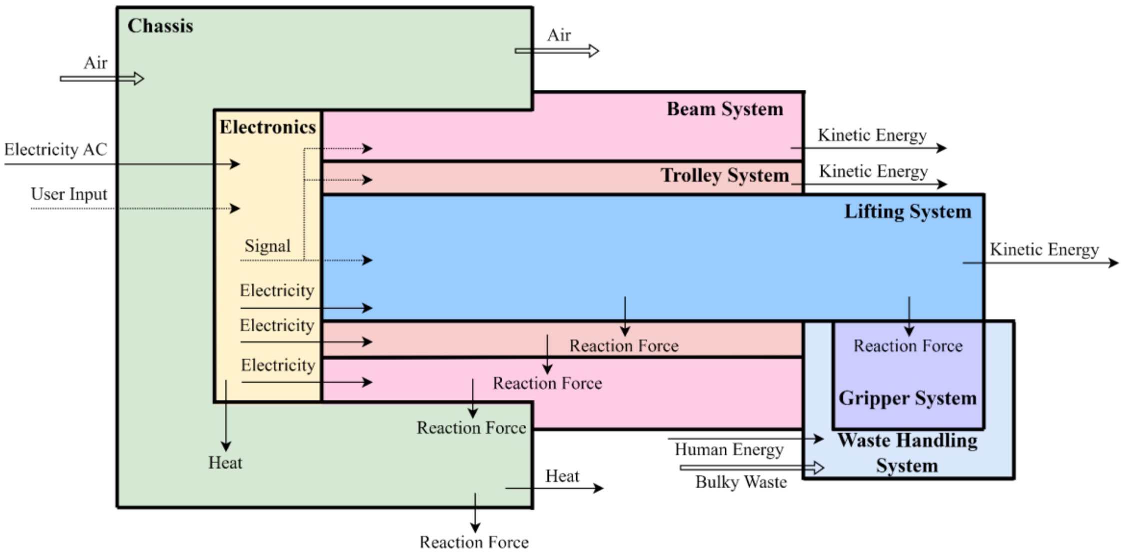

Figure 3.14 Geometric layout of the lifting and loading apparatus.

The chassis encloses almost the entire apparatus, serving not only to protect the technical modules from external influences but also to provide stability to the system as various modules are subjected to vibrations. Of particular importance is the shielding of the electronics module from liquids and other disruptive factors. This module maintains direct connectivity with the beam, the trolley, and the lifting systems, ensuring the required power delivery to these components. The beam module is affixed to the chassis and incorporates both the trolley and the lifting mechanism. This configuration enables the horizontal movements, essential for the loading process. The gripper system is located at the end of the lifting module and is responsible for attaching and securing bulky items. Furthermore, it is connected to the waste handling system, intended to illustrate the user's interaction with the clamp mechanism. Given the mobility of several modules, this layout provides a simplified depiction and does not precisely represent the actual system configuration. Nevertheless, it offers valuable insights into module interactions and highlights spatial requirements.

3.2.3.3 Fundamental & Incidental Interaction Graph

The fundamental interaction graph presents all crucial systems in a structured overview, articulating the intended functions of each module. Furthermore, it delineates the interactions by illustrating the specific connections among modules, thereby aiming to enhance comprehension and clarity. The resulting schematic is presented in Figure 3.15.

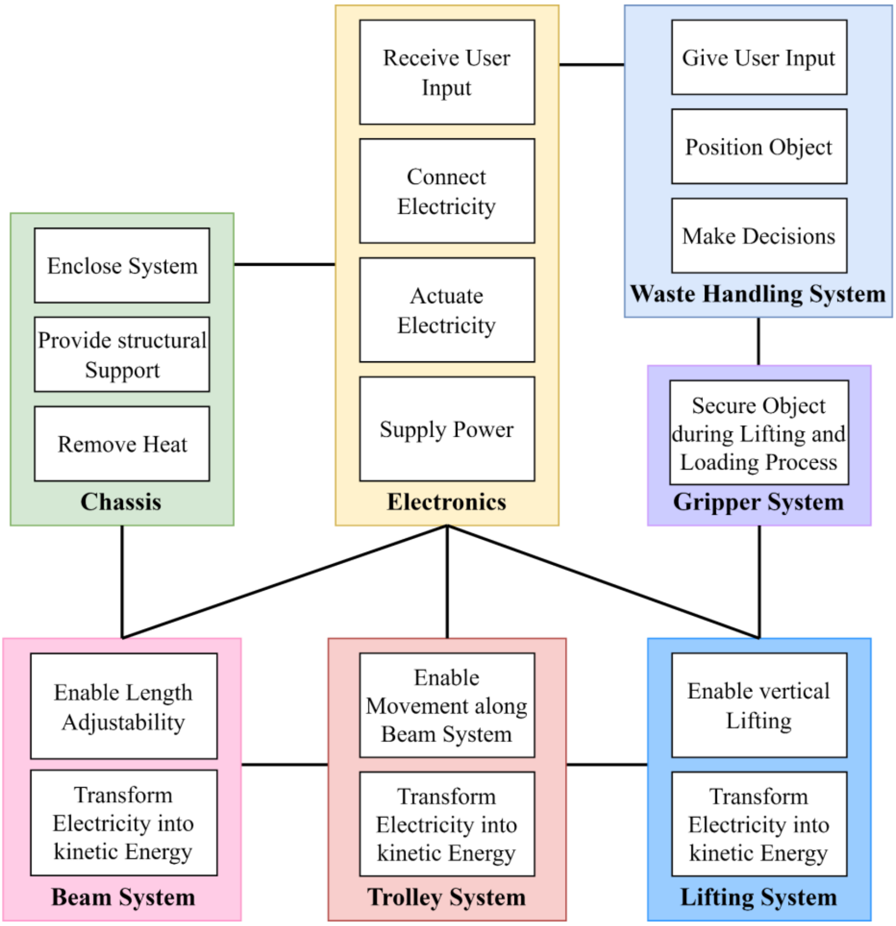

Figure 3.15 Fundamental interaction graph of the various modules and components.

From this schematic representation, it is evident that the waste handling system establishes the basis for the workers' decisions, communicating the respective outgoing signals to the electronics system. Depending on the signal received, the electronics system activates a specific electrically powered module and furnishes it with energy. This energy is subsequently converted by the corresponding systems into kinetic energy, enabling the execution of the desired function. Since the gripper system consists of the mechanical toggle clamp, it requires no electrical energy. Nonetheless, user intervention is necessary to align it with the object to be loaded, hence its connection with the waste handling module.

The final step of this phase is represented by the incidental interaction graph. It focuses on the identification of unintended interactions between components. They describe potential malfunctions of the components and illustrate which modules of the system are affected. The resulting illustration is displayed in Figure 3.16.

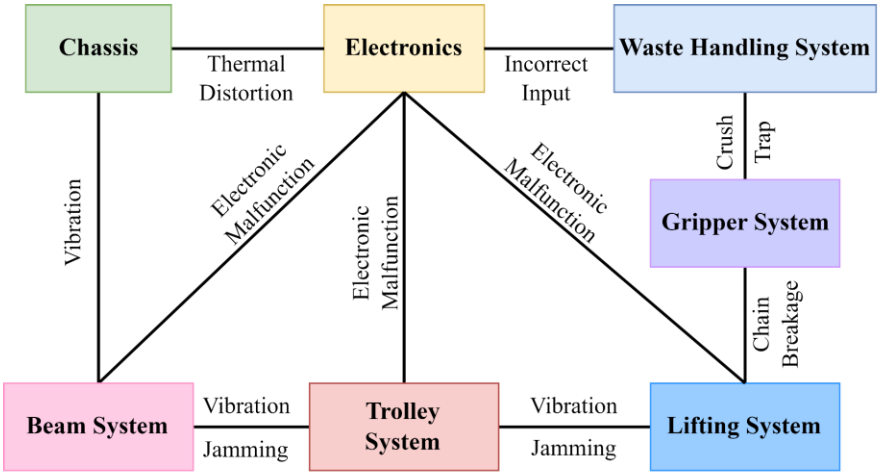

Figure 3.16 Incidental interaction graph of the various modules and components.

In this schematic representation, several crucial insights emerge. Among the pivotal factors to consider are the vibrations introduced by the movements of the electrically driven modules and the motor. These oscillations could lead to blocking or jamming of individual components, resulting in the apparatus becoming inoperative. Furthermore, the system's functionality is critically endangered by potential electronic malfunctions, such as short circuits or loose connections. Moreover, the heat generated by the motor could induce thermal distortions in the chassis, compromising the system's stability.

Risks particularly relevant to the safety of workers are primarily associated with the lifting and gripper systems. The occurrence of a chain rupture within the electric chain hoist could lead to severe injuries of the user or, in the worst case, prove fatal. Should a worker be positioned below the gripper mechanism, there is a risk of entrapment or even crushing. Consequently, it is essential to implement comprehensive and appropriate safety briefings and conduct relevant training to protect workers from these hazardous scenarios.

3.2.4 Detailed Design

In the final stage of the adapted development process, the detailed design is presented. This model includes the selected concepts as well as other necessary parts for the device. An exploded view of the resulting concept solution for the lifting and loading apparatus is depicted in Figure 3.17, providing a comprehensive view of the system's structure and components.

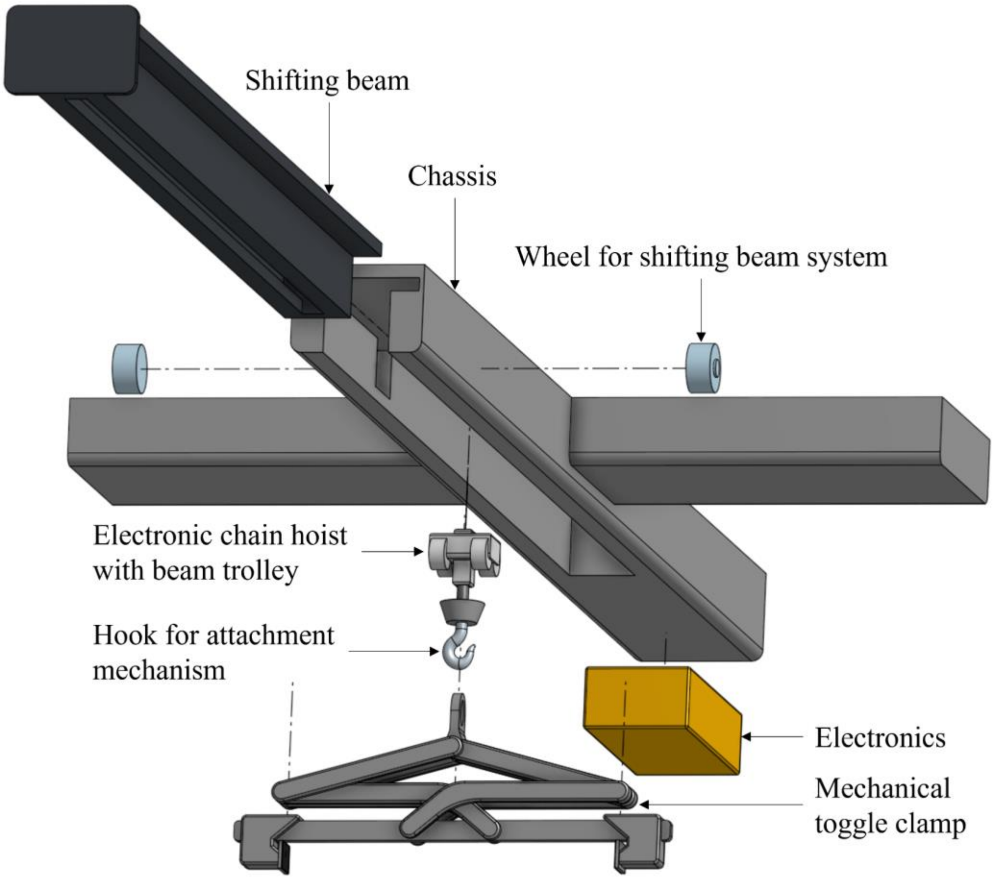

Figure 3.17 Exploded view of the detail design concept.

In the illustration of the apparatus, an X-shaped chassis is recognizable, encapsulating the various components and ensuring both structure and stability to the entire system. The shifting beam is integrated along the longitudinal axis, supported by two electronically driven wheels, thereby enabling lengthwise expansion of the device in one dimension. The electronic chain hoist is merged with the electronic beam trolley into a unified design, which enables the horizontal movements within a cavity of the shifting beam. The mechanical toggle clamp is attached to the electronic chain hoist through a hook. The required power generation occurs in the electronics module located at the rear of the chassis, a strategic placement to protect the sensitive electrical components.

In Figure 3.18, the final concept of the apparatus is presented in a compact view, depicting its intended configuration of the distinct components. Here, the concepts mentioned in the previous section are situated in their actual positions.

Figure 3.18 Compact view of the final design concept.

Subsequently, this design is incorporated into the transport vehicle to provide a more comprehensive depiction of the final concept and its application. Figure 3.19 presents various perspectives of this integrated device.

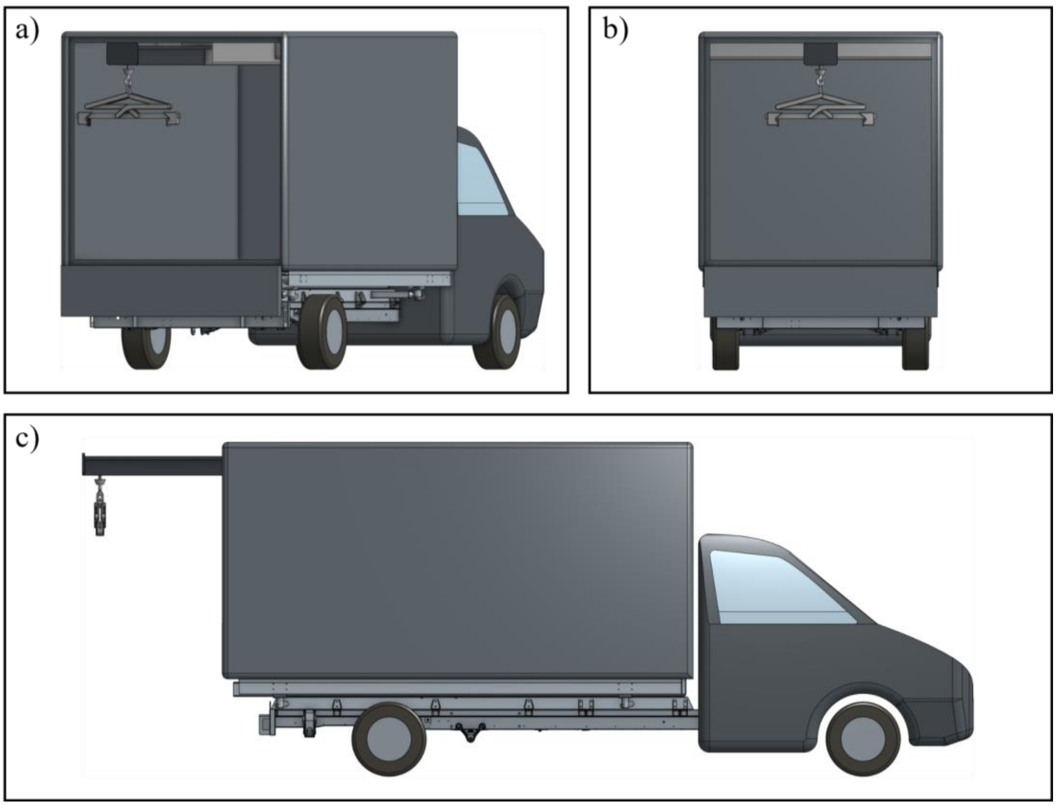

Figure 3.19 Different views of the final design concept integrated into the transport vehicle. a) Isometric view, b) Rear view, c) Side view of the deployed apparatus.

From these illustrations, it is evident that the chassis of the apparatus is attached to the sidewalls of the vehicle. This approach is adopted because these walls are reinforced, making them suitable for bearing significant loads. Contrarily, the vehicle’s roof is not suited for any potential attachment since it is made of tarp-like material and lacks sufficient stability.

The size of the presented mechanical toggle clamp is chosen to ensure sufficient space between the loading area and the clamp mechanism, allowing it to maneuver past already loaded waste. This gripper system requires a tradeoff in geometry to be considered. The larger the distance between the clamps, the more the mechanism expands vertically, as the scissor-like components unfold during the loading of bulky items. Consequently, while a larger clamp distance allows for the loading of a more diverse range of objects, it also results in an increased size of the mechanism, potentially leading to collisions with the already loaded waste.

The maximum possible horizontal extension of the apparatus, relative to the vehicle is depicted in Figure 3.19c. By extending the shifting beam and moving the mobile chain hoist along it, the lifting of bulky goods located outside the vehicle and the loading into the cargo space are enabled. The distance is sufficiently large to prevent objects from colliding with the truck during the lifting process.

A component not included in this detail design concept is a remote control, allowing users to operate the apparatus. This control is intended to be located at the rear of the cargo area and easily accessible. The various mechanisms can then be activated and controlled by the workers through this remote. Also not depicted are the electrical connections and cables of the electronics module and the electrically driven mechanisms. However, the idea is for the electronics module to be directly connected to the vehicle’s battery through cables that run along the cargo space’s front wall, with the connections from the module to the individual mechanisms being housed within the chassis of the apparatus.

In conclusion, the final concept of the lifting and loading apparatus can meet the key requirements and needs of the workers and the company outlined in Table 3.10. Heavy bulky waste no longer needs to be laboriously loaded manually, and employees are no longer compelled to climb into the cargo space. During unloading, the collected waste is not obstructed. Simultaneously, the device does not have to be employed at every waste collection site, thus not hindering other activities. The safety and, above all, the health of the workers can be significantly improved with this technical solution, and the physical strain and mental stress can be reduced. This design, tailored to the employees’ needs, can achieve the desired impact and provide the support that the workers urgently require.

3.3 Concept Evaluation & Decision

3.3.1 Design Proposals

The developed design concept is compared and evaluated against other potential solutions available on the market. The criteria are based on the user needs and product specifications. The resulting information is depicted in Table 3.14.

Table 3.14 Comparison of the developed design concept with products available on the market.

Criteria	Developed Design Concept	Tailgate Lift[1]	Exoskeleton[2]	Loading Crane[3]
Cost	≥ 5000 CHF	3980 CHF	2990 CHF	359 CHF
Estimated lifespan	≥ 5 y	~ 10 y	-	~ 5 y
Worker satisfaction	Very good	Moderate	Bad	Bad
Ease of use	Very good	Good	Moderate	Bad
Loading capacity	≤ 150 kg	≤ 500 kg	-	≤ 450 kg
Weight	≤ 175 kg	154 kg	3 kg	45 kg
Compatibility	Very good	Bad	-	Bad
Safety of user	Very good	Good	Bad	Bad
User involvement	Very low	High	Very high	Very high
Height	≥ 750 mm	1575 mm	-	≤ 2150 mm
Width	2000 mm	1400 mm	-	280 mm
Complexity	High	Moderate	Low	Low
Fulfillment of needs	Very good	Moderate	Poor	Poor
Interference with other activities	Low	High	Low	High

It is evident that the developed design concept is the most expensive product compared to others since it is a custom-made solution tailored to the specific circumstances and workers' needs. It is important to note that the value is a rough estimate, dependent on the material and manufacturing costs. The actual expenses are challenging to predict and will depend on the final decision made by ERZ. Accordingly, the values representing the lifespan of the various products are also rough estimates and are based on market research of similar products and statements of the correspondent manufacturers. The loading capacity of the developed concept is the lowest, yet it is still adequate for the specific application. In contrary, the capacities of the alternative products are rather overdimensioned.

[1] A tailgate lift from the company Palfinger, model C500Van (Palfinger AG, 2023). Their configurator is used to select a compatible product with the vehicle.
[2] A passive exoskeleton from the company Auxivo AG called OmniSuit (Auxivo AG, 2023).
[3] A mechanical loading crane from DEMA GMBH equipped with a manual hydraulic pump and a load hook with a chain (DEMA Distribution AG, 2023).

Compared to the products available on the market, the developed concept offers significant advantages concerning most of the criteria crucial for the workers. None of the other devices meet the requirements and needs of the users to the degree that the design concept does. Despite being the heaviest and most complex solution among the available products, the alternative devices only partially reduce the physical strain and assist the workers in certain tasks. Consequently, users would remain exposed to significant health and safety risks, maintaining the likelihood of potential injuries.

3.3.2 Recommendations to ERZ

As a final step, recommendations and measures for improving the given circumstances and ensuring the health and safety of the workers are formulated to ERZ. These are based on the insights, impressions, and experiences accumulated during the execution of this research.

Based on the results presented in the Chapter 3.1, it is essential and necessary to equip and support the workers with a technical aid. Various potential products are available on the market, but it can be confidently stated that the developed design concept is the best possible device for this specific application, meeting the requirements and needs of the employees. The users are relieved from the laborious physical task of lifting and loading heavy bulky items, no longer facing any health risk regarding this duty. Therefore, it is recommended that ERZ transforms this designed concept into a real product, so it can be put to work as quickly as possible. The conducted development process provides a solid foundation for the design and refinement of the concept, containing useful information and insights that assist in this endeavor. Consequently, it is recommended to incorporate the findings from this research in the realization of the final design concept, especially by involving the workers in the production process. Ultimately, the users are the ones who will engage with the product on a daily basis. Therefore, it is crucial to customize the device in alignment with their demands and incorporate their feedback comprehensively.

Besides this challenging task, as presented in Chapter 3.1.2, the workers must also handle many other physically demanding activities, which are significantly more time-consuming and repetitive. One of these tasks concerns the slit-containers, which are found at every waste collection site. For this reason, it is recommended that the slit-containers undergo a redesign to make the emptying and replacement of the contained bags more ergonomic. Given the vast amount of waste that must be collected from the ground, it is also worthwhile to take measures. Therefore, it is recommended to equip the employees with a mechanical picking tool, which allows for easier collection of small waste from the ground without the workers having to bend down each time.

As demonstrated in Chapter 3.1.3, there is an unequal distribution of waste volumes across the respective routes. This leads to a disproportionate distribution of physical strain on the workers, with some experiencing more significant burdens than others. Therefore, it is recommended that employees rotate among routes, ensuring that they handle equivalent amounts of waste.

Another important factor to consider is raising awareness among the population and residents of Zurich. To not only improve the situation for the workers but also address the problem at its root, it is recommended to encourage and motivate residents to dispose of their waste properly in the future, rather than throwing it on the ground. This endeavor can be accomplished with media presence across all possible social networks, as well as through newspapers and other forms of publicity, to maximize reach and thereby engage and communicate with as many people as possible. The findings resulting from this research, concerning the negative health impacts on the workers, could be utilized as a motivational tool by highlighting potential health consequences and visually presenting them to the residents. For example, one approach could involve placing posters at waste collection sites, displaying illustrations of health impairments associated with the improper disposal of waste.

The final recommendation concerns the communication within ERZ. Through collaboration with the workers and the execution of methods during this research, several insights about daily operations were gathered. These employees are experts in their field, possessing detailed knowledge and know-how regarding the handling of vast quantities of waste. Therefore, it is advised to enhance communication between the workers and the management by establishing new systems for submitting improvement suggestions and valuable inputs from the workers, ensuring that existing expertise is not overlooked. Moreover, regular meetings with the involved staff could be conducted, where specific issues are addressed, and appropriate measures are discussed. This recommendation could significantly benefit the entire company, potentially increasing satisfaction and efficiency.

In summary, by implementing these recommendations, the working conditions can be improved, and the health and safety of the workers can be ensured. How and to what extent these are executed is at the discretion of ERZ. This research serves as a foundation and substantiates the measures using scientific methodologies. Therefore, it is strongly advised to consider and implement all suggested recommendations.

4 Conclusions and Outlook

In this multidisciplinary thesis, the situation and working conditions of certain ERZ workers responsible for recyclables waste collection sites were investigated in detail. The impact and severity of existing physical strains on their health due to their daily activities were assessed.

In collaboration with the workers, detailed information regarding the workflow and essential requirements and needs were identified. The conducted study on daily activities revealed that the most time-consuming tasks are related to handling smaller waste and the emptying and replacement of slit-containers, while the handling of bulky items constitutes only a minor portion of the time spent. The analysis of the collected waste indicated that, on average, Mondays require the collection of three times the amount of waste compared to other weekdays. Furthermore, it was identified that the waste quantities differ between the various tours, implying that the physical strain on the workers is not evenly distributed.

Using established ergonomic risk assessment methods, the severity and implications of the strains were systematically evaluated. Data derived from various evaluation techniques consistently converged upon the same conclusion, highlighting a significant elevation in strain levels. This outcome underscored that the workers are exposed to high physical loads, with a pronounced risk for sustaining long-term injuries and developing musculoskeletal disorders. Although the time spent on handling bulky items was minimal compared to other activities, the resulting strain was significantly increased, necessitating immediate actions. Furthermore, the evaluation of tasks associated with collecting smaller waste also revealed elevated strain indices, whereby the activity of throwing a waste bag ranked among the most strenuous. A general observation from the conducted evaluations suggested that task-specific demands force the workers to adopt disadvantageous and awkward body postures, amplifying the probability of sustaining injuries and chronic health conditions.

Based on the findings and outcomes of the ergonomic risk assessment, an adapted user-centered development process was conducted to design a suitable technical aid. A pivotal requirement for this device was its non-interference with activities unrelated to handling bulky items, as these were the most time-consuming and should remain uninfluenced. This also included the unloading process of the vehicle. Furthermore, the solution needed the capacity to lift heavy objects and load them into the vehicle, all without necessitating workers to enter the loading compartment. Complying with Swiss road regulations posed an additional challenge, further constraining the positioning options. The remaining requirements for the device were based on the identified needs of the workers. Despite these varied demands, a detailed design concept was developed, capable of fulfilling the most crucial needs of the employees. A comparative evaluation of the developed concept against existing market products concluded that the final design concept is the optimal aid solution. No other product in the current market meets the workers' requirements as effectively as the developed design concept. Based on the findings of this research, recommendations for improving the given circumstances and the health and safety of the workers were identified, providing a solid foundation for further measures.

Despite the development of a technical solution and the identification and assessments of worker activities, the health and safety of these individuals are not yet guaranteed. Detailed investigations regarding the strain on workers using sensors and measuring instruments could not be conducted in this thesis. Furthermore, many uncertainties remain in the realization of the final design concept. The precise geometric dimensions of the various mechanisms are yet to be defined, the material selection for different components needs to be considered, and the resulting weight must be factored in. Another critical aspect is the implementation of the electronic components, which must be capable of powering the electrically driven mechanisms. All these factors impact the resulting costs, which could only be roughly estimated within the scope of this thesis. Moreover, the efficiency of the developed design concept and the extent to which it proves useful can only be assessed after its realization.

A crucial subsequent step of this thesis is the realization of the presented final design concept. For this endeavor, the aforementioned aspects and their corresponding mechanisms need to be precisely defined. Additionally, a suitable construction company should be identified to undertake this project. To evaluate the efficiency and efficacy of the developed apparatus, its application should be thoroughly investigated. An extensive study focused on ergonomic improvement could be conducted in collaboration with the workers. In subsequent research, further measures to enhance the working conditions of the employees could be investigated.

Beyond the handling of bulky items, there is a need to address and improve other physically demanding activities to protect the health of the workers. While managing current problems is important, there is also an opportunity to closely investigate other influencing factors and tackle the issue at its core. This could include increasing public awareness regarding proper waste disposal or enhancing communication within ERZ to further improve the exchange of information between workers and their superiors.

To conclude, it must be emphasized once more that the health and well-being of the workers are paramount. Given the unacceptable current working conditions, it is highly recommended to implement the proposed measures immediately. After all, investing in the health of every individual is priceless.

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Appendix A

A.1 Templates

A.1.1 Interview Questions

Table A.1 Questions asked during the anonymized interviews with the workers.

Topic	Question
Current waste disposal	How long have you been working in this position at ERZ? How are the heavy items currently handled? Please describe the exact process. What are the challenges and difficulties encountered in the current process? Please describe a typical sequence of operations when incorrectly disposed waste has to be loaded onto the vehicle How often are extra vehicles needed to pick up this waste? How many times a day is the problem of loading present? How much time do you estimate is needed for the additional loading effort? What type of bulky waste is typically not disposed properly? What is the most common type of bulky waste? Which bulky wastes are the most difficult to handle?
Experience of employees	What health risks and stresses arise for employees during manual waste disposal? Are there any known employee injuries or complaints due to this task? How do you feel about the physical strain of manually lifting and loading heavy objects? What impact does physical strain have on your health and ability to work? Have you personally experienced any pain from the loading task? If you are experiencing pain from the loading task, which part of your body does it affect? Which part of the body is the worst affected? How often do you have pain or tension caused by the loading task?
Level of knowledge	Are you aware of lifting platforms or similar aids? Is there already experience with lifting platforms or comparable solutions in other areas? What benefits do you see in using a lifting platform or comparable solutions for waste disposal?
Requirements of possible solutions	What requirements would a solution need to meet to improve the current process? Do you already have ideas or suggestions for implementing a possible solution? What do you think a possible solution would look like? What should this solution be able to do? What problems could arise with this solution?
Acceptance and implementation	How do you rate the acceptance of such a solution by all stakeholders? Are there any potential challenges or resistance to introducing such a solution?

A.1.2 Quick Exposure Questionnaire

The templates for the reference guide can be downloaded from the corresponding website (Washington State Department of Labor & Industries, 2023).

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)
- A1 Almost neutral?
- A2 Moderately flexed or twisted or side bent?
- A3 Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?
- B1 No
- B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back
- B3 Infrequent (around 3 times per minute or less)?
- B4 Frequent (around 8 times per minute)?
- B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)
- C1 At or below waist height?
- C2 At about chest height?
- C3 At or above shoulder height?

D Is the shoulder/arm movement
- D1 Infrequent (some intermittent movement)?
- D2 Frequent (regular movement with some pauses)?
- D3 Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)
- E1 An almost straight wrist?
- E2 A deviated or bent wrist?

F Are similar motion patterns repeated
- F1 10 times per minute or less?
- F2 11 to 20 times per minute?
- F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?
- G1 No
- G2 Yes, occasionally
- G3 Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?
- H1 Light (5 kg or less)
- H2 Moderate (6 to 10 kg)
- H3 Heavy (11 to 20kg)
- H4 Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?
- J1 Less than 2 hours
- J2 2 to 4 hours
- J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?
- K1 Low (e.g. less than 1 kg)
- K2 Medium (e.g. 1 to 4 kg)
- K3 High (e.g. more than 4 kg)

L Is the visual demand of this task
- L1 Low (almost no need to view fine details)?
- *L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for
- M1 Less than one hour per day or Never?
- M2 Between 1 and 4 hours per day?
- M3 More than 4 hours per day?

N At work do you use vibrating tools for
- N1 Less than one hour per day or Never?
- N2 Between 1 and 4 hours per day?
- N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?
- P1 Never
- P2 Sometimes
- *P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job
- Q1 Not at all stressful?
- Q2 Mildly stressful?
- *Q3 Moderately stressful?
- *Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

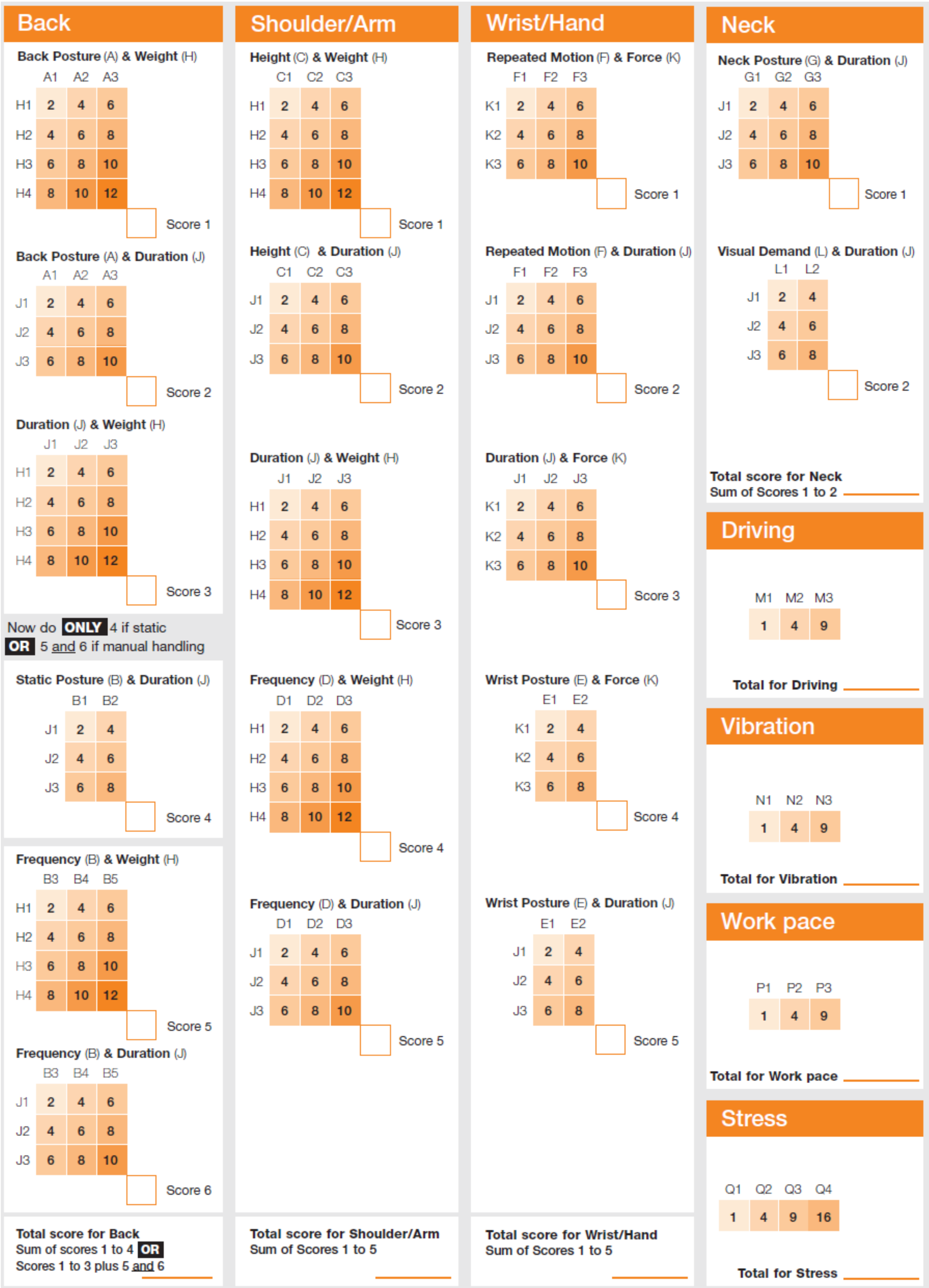
* *Additional details for L, P and Q if appropriate*

*** L**

*** P**

*** Q**

Figure A.1 First page of the Quick Exposure Questionnaire



Back

Back Posture (A) **& Weight** (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1

Back Posture (A) **& Duration** (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2

Duration (J) **& Weight** (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3

Now do **ONLY** 4 if static
OR 5 and 6 if manual handling

Static Posture (B) **& Duration** (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

Score 4

Frequency (B) **& Weight** (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 5

Frequency (B) **& Duration** (J)

	B3	B4	B5
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 6

Total score for Back
Sum of scores 1 to 4 **OR**
Scores 1 to 3 plus 5 and 6

Shoulder/Arm

Height (C) **& Weight** (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1

Height (C) **& Duration** (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2

Duration (J) **& Weight** (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3

Frequency (D) **& Weight** (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 4

Frequency (D) **& Duration** (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 5

Total score for Shoulder/Arm
Sum of Scores 1 to 5

Wrist/Hand

Repeated Motion (F) **& Force** (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 1

Repeated Motion (F) **& Duration** (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2

Duration (J) **& Force** (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 3

Wrist Posture (E) **& Force** (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

Score 4

Wrist Posture (E) **& Duration** (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

Score 5

Total score for Wrist/Hand
Sum of Scores 1 to 5

Neck

Neck Posture (G) **& Duration** (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 1

Visual Demand (L) **& Duration** (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

Score 2

Total score for Neck
Sum of Scores 1 to 2

Driving

M1	M2	M3
1	4	9

Total for Driving

Vibration

N1	N2	N3
1	4	9

Total for Vibration

Work pace

P1	P2	P3
1	4	9

Total for Work pace

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress

Figure A.2 Second page of the Quick Exposure Questionnaire.

A.1.3 Rapid Entire Body Assessment

The templates for the reference guide can be downloaded from the corresponding website (ErgoPlus, 2023a).

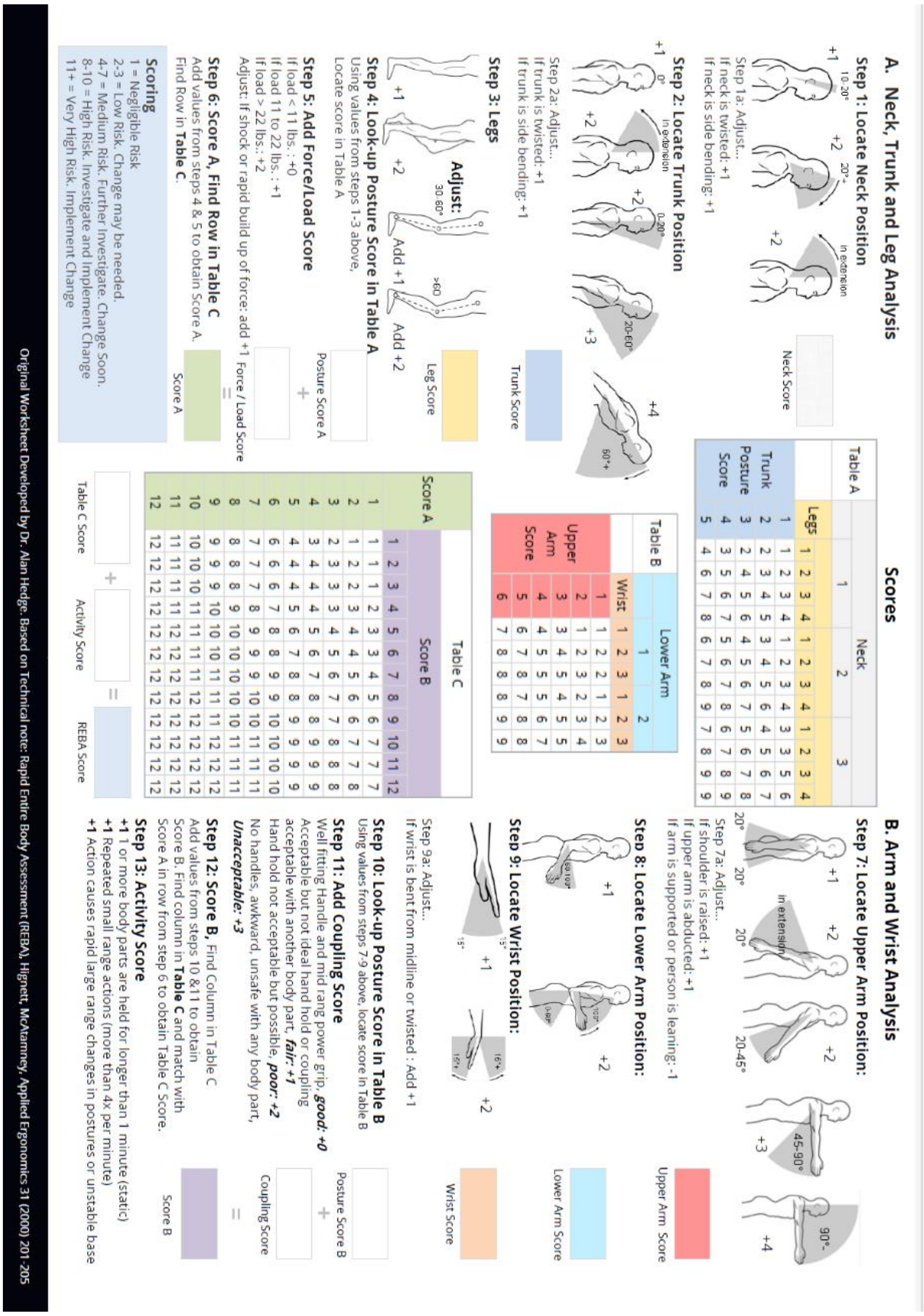


Table A

Trunk Posture Score	Neck 1 / Legs 1	2	3	4	Neck 2 / Legs 1	2	3	4	Neck 3 / Legs 1	2	3	4
1	1	2	3	4	1	2	3	4	3	3	5	6
2	2	3	4	5	3	4	5	6	4	5	6	7
3	2	4	5	6	4	5	6	7	5	6	7	8
4	3	5	6	7	5	6	7	8	6	7	8	9
5	4	6	7	8	6	7	8	9	7	8	9	9

Table B

Upper Arm Score	Lower Arm 1 / Wrist 1	2	3	Lower Arm 2 / Wrist 1	2	3
1	1	2	2	1	2	3
2	1	2	3	2	3	4
3	3	4	5	4	5	5
4	4	5	5	5	6	7
5	6	7	8	7	8	8
6	7	8	8	8	9	9

Table C

Score A	Score B 1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Figure A.3 Paper template for the REBA assessment method.

A.1.4 Rapid Upper Limb Assessment

The templates for the reference guide can be downloaded from the corresponding website (ErgoPlus, 2023b).

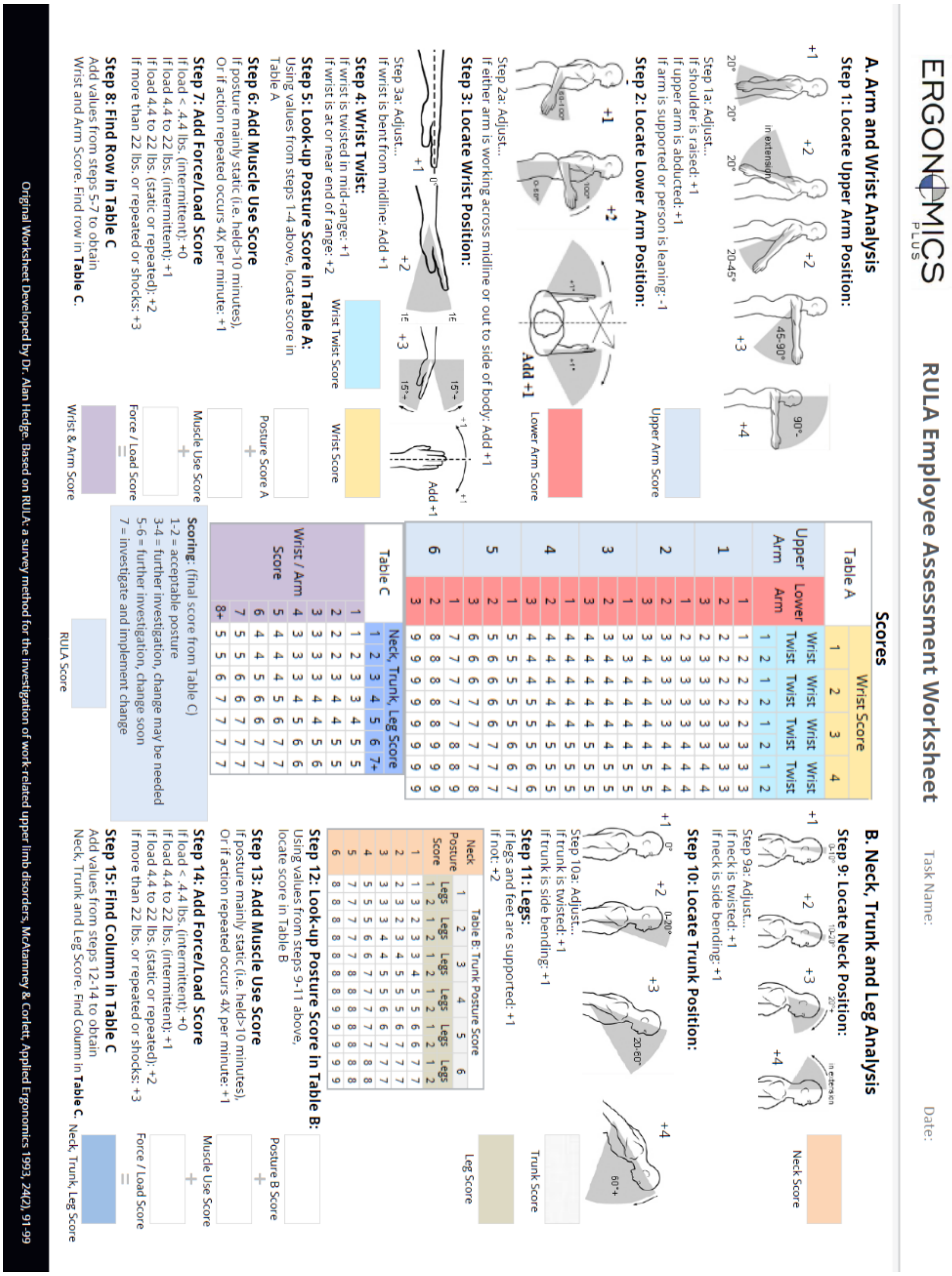


Figure A.4 Paper template for the RULA assessment method.

A.1.5 Key Indicator Methods

The templates for the utilized forms can be found on the corresponding website of the German Federal Institute for Occupational Safety and Health (German Federal Institute for Occupational Safety and Health (BAuA), 2023).

KIM for assessing and designing physical workloads with respect to Whole-Body Forces (KIM-BF)

Workplace/sub-activity:			
Duration of the working day:		Evaluator:	
Duration of the sub-activity:		Date:	

1st step: Determination of time rating points

Total duration[1] [up to … minutes] and/or repetitiveness[2] of the sub-activity per working day:	up to 1	> 1 - 5	> 5 - 10	> 10 - 20	> 20 - 30	> 30 - 45	> 45 - 60	> 60 - 100	> 100 - 150	> 150 - 210	> 210 - 270	> 270 - 360	> 360 - 480
Time rating points	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

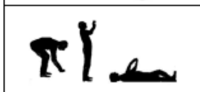
[1] For continuous sub-activities, [2] for discontinuous sub-activities. For explanations in this respect: See guideline.
Please note: If finger-hand forces are applied predominantly, the sub-activity must also be evaluated using the KIM-MHO!

2nd step: Determination of the rating points for other indicators

Force exertion within a standard minute for continuous sub-activities and/or per sub-activity for discontinuous sub-activities		Holding[3] average holding time [seconds]			Moving average movement frequencies [number]			
Level	typical examples as classification aid for orientation purposes	31 - 45[3]	16 - 30	≤ 15	< 5	5 - 15	16 - 30	31 – 45[5]
low	**Low forces** Whole-Body Forces with low forces cannot occur by definition. Where applicable, these sub-activities must be assessed using the KIM-MHO.	-	-	-	-	-	-	-
	Moderate forces (up to 30 % $F_{max}M$) Work with hand-guided tools, such as angle grinders, small chainsaws, hedge trimmers or impact drills < 3 kg / moving loads on roller tracks < 20 kg	**18**	**12**	**6**	**1.5**	**6**	**12**	**18**
	High forces (up to 50 % $F_{max}M$) Work with heavy hand-guided tools, such as angle grinders, large chainsaws, hammer drills3-8 kg / operating high-pressure cleaners or sandblasters/shovelling loads < 4 kg / moving loads on roller tracks 20-50 kg / throwing loads < 3 kg up to max. 5 metres	**25**	**17**	**8**	**2**	**8**	**17**	**25**
	Very high forces (up to 80 % $F_{max}M$) Work with heavy hand-guided tools, such as pneumatic hammers (≥ 8 kg) / shovelling loads 4-8 kg / moving loads on roller tracks > 50-100 kg / throwing loads < 3 kg up to max. 10 metres or 3-5 kg max. 5 metres	**100**	**32**	**15**	**4**	**15**	**32**	**100**
high	**Peak forces**[4] (more than 80 % $F_{max}M$) Pulsed exertion of force such as when working with crowbars, sledgehammers / tipping heavy drums (> 200 kg), transporting heavy pieces of furniture / shovelling loads > 8 kg / moving loads on roller tracks > 100 kg / throwing loads < 3 kg more than 10 metres or ≥ 3 kg more than 5 metres	**100**		**25**	**6**	**25**	**50**	**100**
The sub-activity must be observed and the rating points for the force categories marked. The sum represents the total force rating point.		**Total force rating point:**						
		For women x 1.5:						

[3] The amount of time of holding work is only considered as such in the assessment if one arm is held continuously statically for at least 4 seconds!
[4] These forces might not be exerted at all or might no longer be exerted reliably. This applies to women in particular.
[5] In case of even higher frequencies/holding times, the resulting risk score must be extrapolated linearly or the E version (KIM-BF-E) must be applied.

Symmetry of the application of force	Rating points
Force is applied with both hands and symmetrically	**0**
Force is applied temporarily with one hand and/or asymmetrically: uneven force distribution between the two hands	**2**
Force is applied predominantly with one hand, uneven distribution or direction of forces of both hands	**4**

Body posture[6]		Rating points
	- Standing upright up to a position with the trunk being slightly inclined forward (< 20°) - No twisting	**0**
	- Standing, trunk being more severely inclined forward (20-60°) - Occasional twisting and/or lateral inclination of the trunk identifiable - - Hands occasionally above shoulder level / at a distance from the body	**3**
	- Standing, trunk being severely inclined forward (> 60°) or backward - Frequent twisting and/or lateral inclination of the trunk identifiable - Hands frequently above shoulder level / at a distance from the body - Work in a lying position with hands above/below the body	**6**
	- Combination of more severe forward or backward inclination and lateral inclination/torsion - Constant twisting and/or lateral inclination of the trunk identifiable - Work in a squatting or kneeling position - Hands constantly above shoulder level / at a distance from the body	**9**[7]

[6] Typical body postures are to be taken into account. Rare deviations can be ignored.
[7] Please note: If this category was chosen, it is recommended to evaluate this sub-activity also using the KIM-ABP!

Figure A.5 First page of the KIM template with respect to whole-body forces.

Unfavourable working conditions (specify only where applicable) Note: Here, additional points (intermediate rating points) can be assigned for unfavourable working conditions.		**Intermediate rating points (IRP)**	**∑ IRP**
Hand/arm position and movement: 	occasionally at the limit of the movement ranges	**1**	
	frequently/constantly at the limit of the movement ranges	**2**	
Force transfer/application restricted working objects/tools difficult to grip / greater holding forces required / no shaped grips		**1**	
Force transfer/application considerably hindered working objects/tools hardly possible to grip / slippery, soft, sharp edges / no or unsuitable grips		**2**	
Adverse ambient conditions: exposure to heat, cold and/or vibration[8)]		**1**	
Ambient conditions unfavourable: Exposure to extreme heat, cold and/or vibration[8)]		**2**	
Increased effort caused by restricted spatial conditions Restricted stability and/or restricted space for movement, e.g. height too low or work area of less than 1.5 m² / floor a little bit slippery, slight inclination (up to 5°), obstacles in the work area		**1**	
Significantly increased effort caused by unfavourable spatial conditions Significantly restricted stability and/or freedom of movement, e.g. when working in very confined spaces / floor is very slippery/uneven, stronger inclination (> 5°)		**2**	
Clothes: additional physical workload due to restrictive and heavy protective clothes/equipment (PPE) (e.g. heat protection suits, chemical protection suits, heavy respiratory protective equipment (group 3))		**2**	
None: there are no unfavourable working conditions		**0**	

Indicators not mentioned in the tables are to be taken into account accordingly. Rare deviations can be ignored.
[8)] Please note: If there are physical workloads due to vibrations, they are to be evaluated separately! See http://www.baua.de/vibration/

Work organisation / temporal distribution	**Rating points**
Good: frequent variation of the physical workload situation due to other activities (including other types of physical workload) / without a tight sequence of higher physical workloads within one type of physical workload during a single working day.	**0**
Restricted: rare variation of the physical workload situation due to other activities (including other types of physical workload) / occasional tight sequence of higher physical workloads within one type of physical workload during a single working day.	**2**
Unfavourable: no/hardly any variation of the physical workload situation due to other activities (including other types of physical workload) / frequent tight sequence of higher physical workloads within one type of physical workload during a single working day with concurrent high load peaks.	**4**

3rd step: Evaluation and assessment

		M	**W**
Force exertion			
Symmetry of the application of force	**+**		
Body posture	**+**		
Unfavourable working conditions (∑ IRP)	**+**		
Work organisation / temporal distribution	**+**		

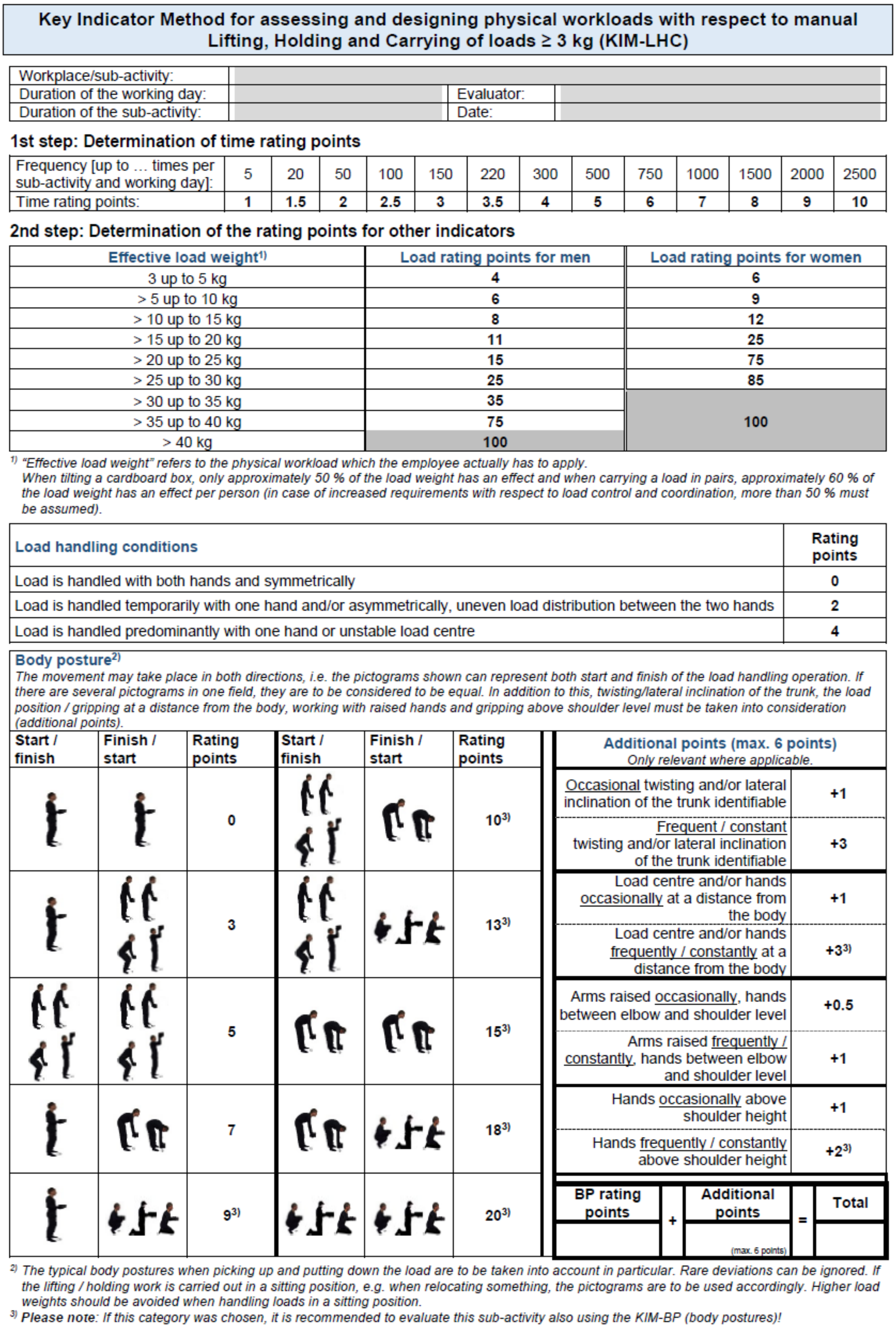
Time rating points	**X**	**Total of indicator rating points:**			**=**	**Results M**	**Results W**

The risk score calculated and the table below can be used as the basis for a rough evaluation:

Risk	Risk range		Intensity of load[*)]	a) Probability of physical overload b) Possible health consequences	Measures
	1	< 20 points	low	a) Physical overload is unlikely. b) No health risk is to be expected.	None
	2	20 - < 50 points	slightly increased	a) Physical overload is possible for less resilient persons. b) Fatigue, low-grade adaptation problems which can be compensated for during leisure time	For less resilient persons, workplace redesign and other prevention measures may be helpful.
	3	50 - < 100 points	substantially increased	a) Physical overload is also possible for normally resilient persons. b) Disorders (pain), possibly including dysfunctions, reversible in most cases, without morphological manifestation	Workplace redesign and other prevention measures should be considered.
	4	≥ 100 points	high	a) Physical overload is likely. b) More pronounced disorders and/or dysfunctions, structural damage with pathological significance	Workplace redesign measures are necessary. Other prevention measures should be considered.

[*)] The boundaries between the risk ranges are fluid because of the individual working techniques and performance conditions. The classification may therefore only be regarded as an orientation aid. Basically, it must be assumed that the probability of physical overload will increase as the risk scores rise.

Figure A.6 Second page of the KIM template with respect to whole-body forces.



Key Indicator Method for assessing and designing physical workloads with respect to manual Lifting, Holding and Carrying of loads ≥ 3 kg (KIM-LHC)

Workplace/sub-activity:			
Duration of the working day:		Evaluator:	
Duration of the sub-activity:		Date:	

1st step: Determination of time rating points

Frequency [up to … times per sub-activity and working day]:	5	20	50	100	150	220	300	500	750	1000	1500	2000	2500
Time rating points:	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

2nd step: Determination of the rating points for other indicators

Effective load weight[1]	Load rating points for men	Load rating points for women
3 up to 5 kg	**4**	**6**
> 5 up to 10 kg	**6**	**9**
> 10 up to 15 kg	**8**	**12**
> 15 up to 20 kg	**11**	**25**
> 20 up to 25 kg	**15**	**75**
> 25 up to 30 kg	**25**	**85**
> 30 up to 35 kg	**35**	**100**
> 35 up to 40 kg	**75**	
> 40 kg	**100**	

[1] *"Effective load weight" refers to the physical workload which the employee actually has to apply. When tilting a cardboard box, only approximately 50 % of the load weight has an effect and when carrying a load in pairs, approximately 60 % of the load weight has an effect per person (in case of increased requirements with respect to load control and coordination, more than 50 % must be assumed).*

Load handling conditions	Rating points
Load is handled with both hands and symmetrically	**0**
Load is handled temporarily with one hand and/or asymmetrically, uneven load distribution between the two hands	**2**
Load is handled predominantly with one hand or unstable load centre	**4**

Body posture[2]

The movement may take place in both directions, i.e. the pictograms shown can represent both start and finish of the load handling operation. If there are several pictograms in one field, they are to be considered to be equal. In addition to this, twisting/lateral inclination of the trunk, the load position / gripping at a distance from the body, working with raised hands and gripping above shoulder level must be taken into consideration (additional points).

Start / finish	Finish / start	Rating points	Start / finish	Finish / start	Rating points
		0			10[3]
		3			13[3]
		5			15[3]
		7			18[3]
		9[3]			20[3]

Additional points (max. 6 points) *Only relevant where applicable.*	
Occasional twisting and/or lateral inclination of the trunk identifiable	**+1**
Frequent / constant twisting and/or lateral inclination of the trunk identifiable	**+3**
Load centre and/or hands occasionally at a distance from the body	**+1**
Load centre and/or hands frequently / constantly at a distance from the body	**+3[3]**
Arms raised occasionally, hands between elbow and shoulder level	**+0.5**
Arms raised frequently / constantly, hands between elbow and shoulder level	**+1**
Hands occasionally above shoulder height	**+1**
Hands frequently / constantly above shoulder height	**+2[3]**

BP rating points	+	Additional points	=	Total
		(max. 6 points)		

[2] *The typical body postures when picking up and putting down the load are to be taken into account in particular. Rare deviations can be ignored. If the lifting / holding work is carried out in a sitting position, e.g. when relocating something, the pictograms are to be used accordingly. Higher load weights should be avoided when handling loads in a sitting position.*

[3] ***Please note:** If this category was chosen, it is recommended to evaluate this sub-activity also using the KIM-BP (body postures)!*

Figure A.7 First page of the KIM template with respect to manual lifting, holding, and carrying of loads.

Unfavourable working conditions (specify only where applicable) *Indicators not mentioned in the tables are to be taken into account accordingly.* *Rare deviations can be ignored.*		**Intermediate rating points IRP**	**∑ IRP**
Hand/arm position and movement: 	occasionally at the limit of the movement ranges	**1**	
	frequently/constantly at the limit of the movement ranges	**2**	
Force transfer/application restricted: loads difficult to grip / greater holding forces required / no shaped grips / work gloves		**1**	
Force transfer/application considerably hindered: loads hardly possible to grip / slippery, soft, sharp edges / no/unsuitable grips / work gloves		**2**	
Adverse ambient conditions: unfavourable weather conditions and/or physical workloads caused by heat, draught, cold, wet		**1**	
Spatial conditions restricted: work area of less than 1.5 m², floor is moderately dirty and slightly uneven, slight inclination of up to 5°, slightly restricted stability, load must be positioned precisely		**1**	
Spatial conditions unfavourable: significantly restricted freedom of movement or space for movement is not high enough, working in confined spaces, floor is very dirty, uneven or roughly cobbled, steps / potholes, stronger inclination of 5-10°, restricted stability, load must be positioned very precisely		**2**[4)]	
Clothes: additional physical workload due to impairing clothes or equipment (e.g. when wearing heavy rain jackets, whole-body protection suits, respiratory protective equipment, tool belts or the like)		**1**	
Difficulties due to holding / carrying: The load has to be held between > 5 and 10 seconds or carried over a distance between > 2 m and 5 m.		**2**	
Significant difficulties due to holding / carrying: The load has to be held > 10 seconds or carried over a distance > 5 m.		**5**[4)]	
None: there are no unfavourable working conditions		**0**	

4) Please note: If there are unfavourable spatial conditions when carrying loads or if the load has to be carried over distances > 10 m, this sub-activity is to be evaluated using the KIM-BM!

Work organisation / temporal distribution	**Rating points**
Good: frequent variation of the physical workload situation due to other activities (including other types of physical workload) / without a tight sequence of higher physical workloads within one type of physical workload during a single working day.	**0**
Restricted: rare variation of the physical workload situation due to other activities (including other types of physical workload) / occasional tight sequence of higher physical workloads within one type of physical workload during a single working day.	**2**
Unfavourable: no/hardly any variation of the physical workload situation due to other activities (including other types of physical workload) / frequent tight sequence of higher physical workloads within one type of physical workload during a single working day with concurrent high load peaks.	**4**

3rd step: Evaluation and assessment

		Men	**Women**
Effective load weight			
Load handling conditions	**+**		
Total body posture	**+**		
Unfavourable working conditions (∑ IRP)	**+**		
Work organisation / temporal distribution	**+**		

Time rating points	**X**	**Total of indicator rating points:**	Men	Women	**=**	**Results** Men	**Results** Women

The risk score calculated and the table below can be used as the basis for a rough evaluation:

Risk	**Risk range**		**Intensity of load**[*)]	**a) Probability of physical overload** **b) Possible health consequences**	**Measures**
	1	< 20 points	low	a) Physical overload is unlikely. b) No health risk is to be expected.	None
	2	20 - < 50 points	slightly increased	a) Physical overload is possible for less resilient persons. b) Fatigue, low-grade adaptation problems which can be compensated for during leisure time	For less resilient persons, workplace redesign and other prevention measures may be helpful.
	3	50 - < 100 points	substantially increased	a) Physical overload is also possible for normally resilient persons. b) Disorders (pain), possibly including dysfunctions, reversible in most cases, without morphological manifestation	Workplace redesign and other prevention measures should be considered.
	4	≥ 100 points	high	a) Physical overload is likely. b) More pronounced disorders and/or dysfunctions, structural damage with pathological significance	Workplace redesign measures are necessary. Other prevention measures should be considered.

**) The boundaries between the risk ranges are fluid because of the individual working techniques and performance conditions. The classification may therefore only be regarded as an orientation aid. Basically,it must be assumed that the probability of physical overload will increase as the risk scores rise.*

Figure A.8 Second page of the KIM template with respect to manual lifting, holding, and carrying of loads.

Key Indicator Method for assessing and designing physical workloads with respect to Body Movement (KIM-BM)

Workplace/sub-activity:			
Duration of the working day:		Evaluator:	
Duration of the sub-activity:		Date:	

1st step: Determination of time rating points

Total duration of the sub-activity [up to … minutes] per working day:	up to 1	> 1 - 5	> 5 - 10	> 10 - 20	> 20 - 30	> 30 - 45	> 45 - 60	> 60 - 100	> 100 - 150	> 150 - 210	> 210 - 270	> 270 - 360	> 360 - 480
Time rating points	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

2nd step: Determination of the rating points for other indicators

A Body Movement without using equipment

Type	Description		Carried load: without / < 3 kg	3 … 10 kg	> 10 … 15 kg	> 15 … 20 kg	> 20 … 25 kg	> 25 … 30 kg	> 30 … 35 kg	> 35 … 40 kg	> 40 kg
	Walking	Slowly	**4**	**6**	**8**	**10**	**12**	**14**	**25**	**35**	**100** [1]
		At a moderate pace (3 … 5 km/h)	**8**	**10**	**12**	**14**	**16**	**18**	**30**	**40**	
		Quickly	**12**	**14**	**16**	**18**	**20**	**22**	**35**	**50**	
	Climbing	Angle of inclination < 5°	**10**	**12**	**14**	**16**	**18**	**20**	**35**	**50**	
		Angle of inclination 5 - 15°	**12**	**14**	**16**	**18**	**20**	**22**	**35**	**50**	
		Angle of inclination > 15°	**24**	**26**	**28**	**30**	**32**	**34**	**40**	**50**	
	Climbing stairs	Normal stairs	**18**	**20**	**22**	**24**	**26**	**50**	**100** [1]		
		Steep stairs (35 … 50°)	**24**	**26**	**28**	**30**	**50**	**100** [1]			
		Very steep stairs (> 50°)	**30**	**32**	**34**	**50**	**100** [1]				
	Climbing ladders Angle of inclination 65 … 75°		**24**	**26**	**50**	**100** [1]					
	Climbing Angle of inclination > 80° Vertical movement on step irons, vertical ladders, manhole ladders		**30**	**32**	**50**	**100** [1]					
	Crawling[2]**, walking with a severe stoop** Predominantly horizontal movement in low-ceiling rooms, tunnels, maintenance platforms, channels		**24**	**26**	**50**	**100** [1]					

1) This combination of type of movement and transport of loads leads to an increased risk even with short exposure times.
2) For this type of movement, the sub-activity must also be evaluated using the KIM-ABP Part C.

Location of the load centre for A	Carried load: 3 up to 15 kg	> 15 … 30 kg	> 30 kg
No load or load < 3 kg or load is close to the body in a carrying frame or backpack on the shoulders	**0**		
Load close to the body, held in the hands or carried on one shoulder	**4**	**8**	**12**
Load at a distance from the body, held in the hands [3]	**8**	**12**	**16**

Trunk posture for A		Carried load: 0 up to 15 kg	> 15 … 30 kg	> 30 kg
Trunk clearly inclined forward and/or twisting and/or lateral inclination of the trunk identifiable	Occasionally	**2**	**4**	**6**
	Frequently to constantly [3]	**4**	**6**	**8**

3) Please note: If unfavourable arm or trunk postures occur frequently to constantly, the sub-activity must also be evaluated using the KIM-LHC (for load ≥ 3 kg) or the KIM-ABP (no load or load < 3 kg).

Unfavourable working conditions for A (Specify only where applicable. Indicators not mentioned in the tables are to be taken into account accordingly. Rare deviations can be ignored.)	**Rating points**	
Restricted: narrow space for movement (e.g. fall protection by means of safety cage) / reduced stability due to movable or inclined standing surface / **sand / gravel path**	**3**	
Severely restricted: freedom of movement hindered / no technical climbing aids (natural conditions) / **open country**	**5**	
Critical: freedom of movement severely hindered due to confined spaces and danger points / restricted view / no resting platforms / mountaineering / respiratory protective equipment / **muddy ground**	**15**	
Climate: extreme climatic influences, such as heat, wind, snow (graded as rarely/occasionally and frequently/constantly)	**4**	**8**
Total of "Restricted", "Severely restricted" or "Critical" and "Climate" (if applicable)		

Figure A.9 First page of the KIM template with respect to body movements.

B Body Movement when driving by muscle power

Type	Description	Load weight to be moved including transport device [4)]		
		up to 50 kg	> 50 ... 150 kg	> 150 kg
	Slowly < 10 km/h	3	6	9
	At a moderate pace 10 ... 15 km/h	6	10	14
	Quickly > 15 km/h	9	15	21

Driveway - unfavourable working conditions for B (Specify only where applicable. Indicators not mentioned in the tables are to be taken into account accordingly. Rare deviations can be ignored.)	Load weight to be moved including transport device [4)]		
	up to 50 kg	> 50 ... 150 kg	> 150 kg
Driveway restricted: earth or roughly cobbled driveway, potholes, heavy soiling, temporary ascents	8	12	16
Climate: extreme climatic influences, such as heat, wind, snow	rarely/occasionally	frequently/constantly	
	4	8	
Total			

4) If supported by electric operation, the rating points must be divided in half.

Work organisation / temporal distribution	Rating points
Good: frequent variation of the physical workload situation due to other activities (including other types of physical workload) / without a tight sequence of higher physical workloads within one type of physical workload during a single working day.	0
Restricted: rare variation of the physical workload situation due to other activities (including other types of physical workload) / occasional tight sequence of higher physical workloads within one type of physical workload during a single working day.	2
Unfavourable: no/hardly any variation of the physical workload situation due to other activities (including other types of physical workload) / frequent tight sequence of higher physical workloads within a type of physical workload during a working day with concurrent high load peaks.	4

3rd step: Evaluation and assessment

A:
Body movement without using equipment

Location of the load centre (only for A, otherwise 0) +

Twisting and/or lateral inclination of the trunk (only for A, otherwise 0) +

Unfavourable working conditions (only for A, otherwise 0) +

B:
Body movement when driving by muscle power +

Driveway (only for B, otherwise 0) +

Work organisation / temporal distribution A and B +

Results

In case of female employees x 1.3

Time rating points **X** **Total of indicator rating points:** = **M** **x 1.3** **W**

The risk score calculated and the table below can be used as the basis for a rough evaluation:					
Risk	**Risk range**	**Intensity of load[*)]**	**a) Probability of physical overload b) Possible health consequences**	**Measures**
1	< 20 points	low	a) Physical overload is unlikely. b) No health risk is to be expected.	None
2	20 - < 50 points	slightly increased	a) Physical overload is possible for less resilient persons. b) Fatigue, low-grade adaptation problems which can be compensated for during leisure time	For less resilient persons, workplace redesign and other prevention measures may be helpful.
3	50 - < 100 points	substantially increased	a) Physical overload is also possible for normally resilient persons. b) Disorders (pain), possibly including dysfunctions, reversible in most cases, without morphological manifestation	Workplace redesign and other prevention measures should be considered.
4	≥ 100 points	high	a) Physical overload is likely. b) More pronounced disorders and/or dysfunctions, structural damage with pathological significance	Workplace redesign measures are necessary. Other prevention measures should be considered.

**) The boundaries between the risk ranges are fluid because of the individual working techniques and performance conditions. The classification may therefore only be regarded as an orientation aid. Basically, it must be assumed that the probability of physical overload will increase as the risk scores rise.*

Figure A.10 Second page of the KIM template with respect to body movements.

baua:
Bundesanstalt für Arbeitsschutz
und Arbeitsmedizin

PDF-Formular zur belastungsartspezifischen Zusammenfassung der Beurteilungen mit den Leitmerkmalmethoden über verschiedene Teil-Tätigkeiten eines Arbeitstages (LMM-Multi-E)

Bezeichnung des (typischen) Arbeitsplatzes / Arbeitstages:	Die Beurteilung ist gültig für:		
(Bezeichnung)	Männer	Frauen	Beide

Übersicht der LMM-Beurteilungen aller Teil-Tätigkeiten eines Arbeitstages

k Lfd. # Import	LMM Belas-tungs-art (LMM)	T_k Bezeichnung der Teil-Tätigkeit	t_k Reale Zeit-dauer [min]	ZW_k Zeit-wichtung [Pkt.]	I_k Intensität = Summe der Merkmalswich-tungen [Pkt.]	$PW_k = ZW_k * I_k$ Punkt-wert pro Teil-Tätig-keit [Pkt.]	$PW_{k: extrap. 8h}$ Hochrechnung der Belastung durch eine Tä-tigkeit dieser Art auf 8h [Pkt.]
Bsp.	*MA*	*Polstern*	*240*	*4*	*12*	*48*	*96*
#01	---	---	0	0.0	0.0	---	---
#02	---	---	0	0.0	0.0	---	---
#03	---	---	0	0.0	0.0	---	---
#04	---	---	0	0.0	0.0	---	---
#05	---	---	0	0.0	0.0	---	---
#06	---	---	0	0.0	0.0	---	---
#07	---	---	0	0.0	0.0	---	---
#08	---	---	0	0.0	0.0	---	---
#09	---	---	0	0.0	0.0	---	---
#10	---	---	0	0.0	0.0	---	---
#11	---	---	0	0.0	0.0	---	---
#12	---	---	0	0.0	0.0	---	---
#13	---	---	0	0.0	0.0	---	---
#14	---	---	0	0.0	0.0	---	---
#15	---	---	0	0.0	0.0	---	---
#16	---	---	0	0.0	0.0	---	---
#17	---	---	0	0.0	0.0	---	---
#18	---	---	0	0.0	0.0	---	---
#19	---	---	0	0.0	0.0	---	---
#20	---	---	0	0.0	0.0	---	---
#21	---	---	0	0.0	0.0	---	---
#22	---	---	0	0.0	0.0	---	---
#23	---	---	0	0.0	0.0	---	---
#24	---	---	0	0.0	0.0	---	---

Zusammenfassung über den gesamten Arbeitstag pro physische Belastungsart

LMM	Physische Belastungsarten	Kumulative Zeitdauer t_{LMM} [min]	Anzahl Teil-Tätigkeiten pro LMM n_{LMM}	PW_{LMM8h} über alle Teil-Tätigkeiten [Punkte]	Risiko-bereich
HHT	Heben, Halten und Tragen v. Lasten	0	0	---	---
ZS	Ziehen und Schieben von Lasten	0	0	---	---
MA	Manuelle Arbeitsprozesse	0	0	---	---
GK	Aufbringen von Ganzkörperkräften	0	0	---	---
KB	Körperfortbewegung	0	0	---	---
KH	Körperzwangshaltungen	0	0	---	---
nb	Nicht beurteilte Teil-Tätigkeiten	0	0	---	---
alle	**Gesamter Arbeitstag**	0	0	**---**	**---**

Datum		Unterschrift	

Zurücksetzen | Aktualisieren | Export als FDF | FDF importieren | Nutzungshinweise für das Formular

Figure A.11 Interactive form template for assessing multiple Key Indicator Methods (only available in German).

A.2 Assessments

A.2.1 Quick Exposure Questionnaire

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

- [ ] A1 Almost neutral?
- [ ] A2 Moderately flexed or twisted or side bent?
- [x] A3 Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?

- [ ] B1 No
- [ ] B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

- [ ] B3 Infrequent (around 3 times per minute or less)?
- [x] B4 Frequent (around 8 times per minute)?
- [ ] B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

- [ ] C1 At or below waist height?
- [ ] C2 At about chest height?
- [x] C3 At or above shoulder height?

D Is the shoulder/arm movement

- [ ] D1 Infrequent (some intermittent movement)?
- [ ] D2 Frequent (regular movement with some pauses)?
- [x] D3 Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)

- [ ] E1 An almost straight wrist?
- [x] E2 A deviated or bent wrist?

F Are similar motion patterns repeated

- [ ] F1 10 times per minute or less?
- [x] F2 11 to 20 times per minute?
- [ ] F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

- [ ] G1 No
- [x] G2 Yes, occasionally
- [ ] G3 Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

- [ ] H1 Light (5 kg or less)
- [ ] H2 Moderate (6 to 10 kg)
- [ ] H3 Heavy (11 to 20kg)
- [x] H4 Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

- [x] J1 Less than 2 hours
- [ ] J2 2 to 4 hours
- [ ] J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

- [ ] K1 Low (e.g. less than 1 kg)
- [ ] K2 Medium (e.g. 1 to 4 kg)
- [x] K3 High (e.g. more than 4 kg)

L Is the visual demand of this task

- [x] L1 Low (almost no need to view fine details)?
- [ ] *L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for

- [ ] M1 Less than one hour per day or Never?
- [x] M2 Between 1 and 4 hours per day?
- [ ] M3 More than 4 hours per day?

N At work do you use vibrating tools for

- [x] N1 Less than one hour per day or Never?
- [ ] N2 Between 1 and 4 hours per day?
- [ ] N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?

- [x] P1 Never
- [ ] P2 Sometimes
- [ ] *P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job

- [ ] Q1 Not at all stressful?
- [x] Q2 Mildly stressful?
- [ ] *Q3 Moderately stressful?
- [ ] *Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

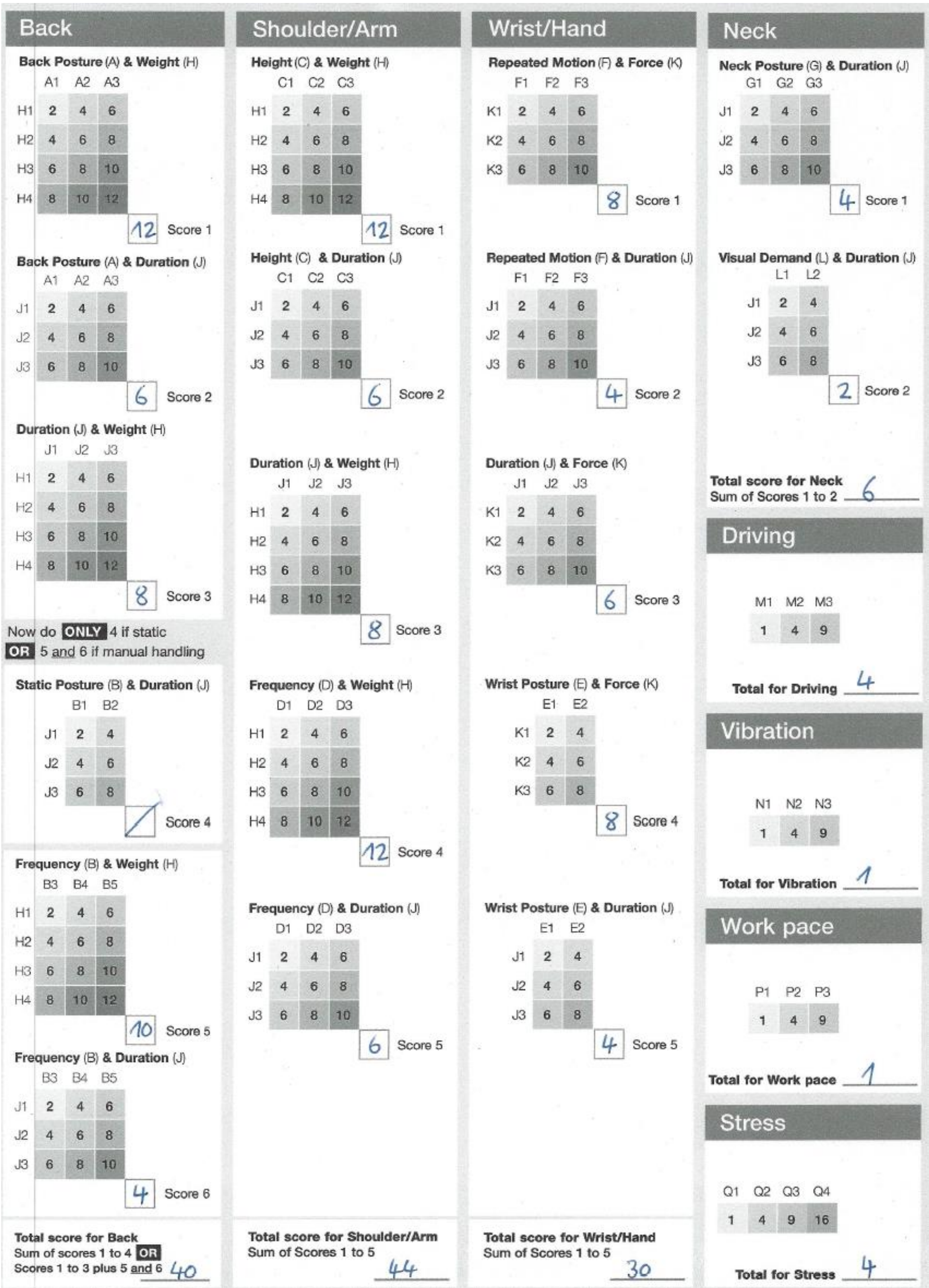
* *Additional details for L, P and Q if appropriate*

*** L**

*** P**

*** Q**

Figure A.12 First page of the conducted Quick Exposure Questionnaire for worker 1.



Back

Back Posture (A) & Weight (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 1

Back Posture (A) & Duration (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

6 Score 2

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

8 Score 3

Now do **ONLY** 4 if static
OR 5 and 6 if manual handling

Static Posture (B) & Duration (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

/ Score 4

Frequency (B) & Weight (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

10 Score 5

Frequency (B) & Duration (J)

	B3	B4	B5
J1	2	4	6
J2	4	6	8
J3	6	8	10

4 Score 6

Total score for Back
Sum of scores 1 to 4 **OR**
Scores 1 to 3 plus 5 and 6 40

Shoulder/Arm

Height (C) & Weight (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 1

Height (C) & Duration (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

6 Score 2

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

8 Score 3

Frequency (D) & Weight (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 4

Frequency (D) & Duration (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

6 Score 5

Total score for Shoulder/Arm
Sum of Scores 1 to 5 44

Wrist/Hand

Repeated Motion (F) & Force (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

8 Score 1

Repeated Motion (F) & Duration (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

4 Score 2

Duration (J) & Force (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

6 Score 3

Wrist Posture (E) & Force (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

8 Score 4

Wrist Posture (E) & Duration (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

4 Score 5

Total score for Wrist/Hand
Sum of Scores 1 to 5 30

Neck

Neck Posture (G) & Duration (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

4 Score 1

Visual Demand (L) & Duration (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

2 Score 2

Total score for Neck
Sum of Scores 1 to 2 6

Driving

M1	M2	M3
1	4	9

Total for Driving 4

Vibration

N1	N2	N3
1	4	9

Total for Vibration 1

Work pace

P1	P2	P3
1	4	9

Total for Work pace 1

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress 4

Figure A.13 Second page of the conducted Quick Exposure Questionnaire for worker 1.

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

- A1 [ ] Almost neutral?
- A2 [ ] Moderately flexed or twisted or side bent?
- A3 [X] Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?

- B1 [ ] No
- B2 [ ] Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

- B3 [ ] Infrequent (around 3 times per minute or less)?
- B4 [X] Frequent (around 8 times per minute)?
- B5 [ ] Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

- C1 [ ] At or below waist height?
- C2 [ ] At about chest height?
- C3 [X] At or above shoulder height?

D Is the shoulder/arm movement

- D1 [ ] Infrequent (some intermittent movement)?
- D2 [ ] Frequent (regular movement with some pauses)?
- D3 [X] Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)

- E1 [ ] An almost straight wrist?
- E2 [X] A deviated or bent wrist?

F Are similar motion patterns repeated

- F1 [ ] 10 times per minute or less?
- F2 [X] 11 to 20 times per minute?
- F3 [ ] More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

- G1 [ ] No
- G2 [X] Yes, occasionally
- G3 [ ] Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

- H1 [ ] Light (5 kg or less)
- H2 [ ] Moderate (6 to 10 kg)
- H3 [ ] Heavy (11 to 20kg)
- H4 [X] Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

- J1 [ ] Less than 2 hours
- J2 [ ] 2 to 4 hours
- J3 [X] More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

- K1 [ ] Low (e.g. less than 1 kg)
- K2 [X] Medium (e.g. 1 to 4 kg)
- K3 [ ] High (e.g. more than 4 kg)

L Is the visual demand of this task

- L1 [X] Low (almost no need to view fine details)?
- *L2 [ ] High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for

- M1 [ ] Less than one hour per day or Never?
- M2 [X] Between 1 and 4 hours per day?
- M3 [ ] More than 4 hours per day?

N At work do you use vibrating tools for

- N1 [X] Less than one hour per day or Never?
- N2 [ ] Between 1 and 4 hours per day?
- N3 [ ] More than 4 hours per day?

P Do you have difficulty keeping up with this work?

- P1 [ ] Never
- P2 [X] Sometimes
- *P3 [ ] Often

* *If Often, please give details in the box below*

Q In general, how do you find this job

- Q1 [X] Not at all stressful?
- Q2 [ ] Mildly stressful?
- *Q3 [ ] Moderately stressful?
- *Q4 [ ] Very stressful?

* *If Moderately or Very, please give details in the box below*

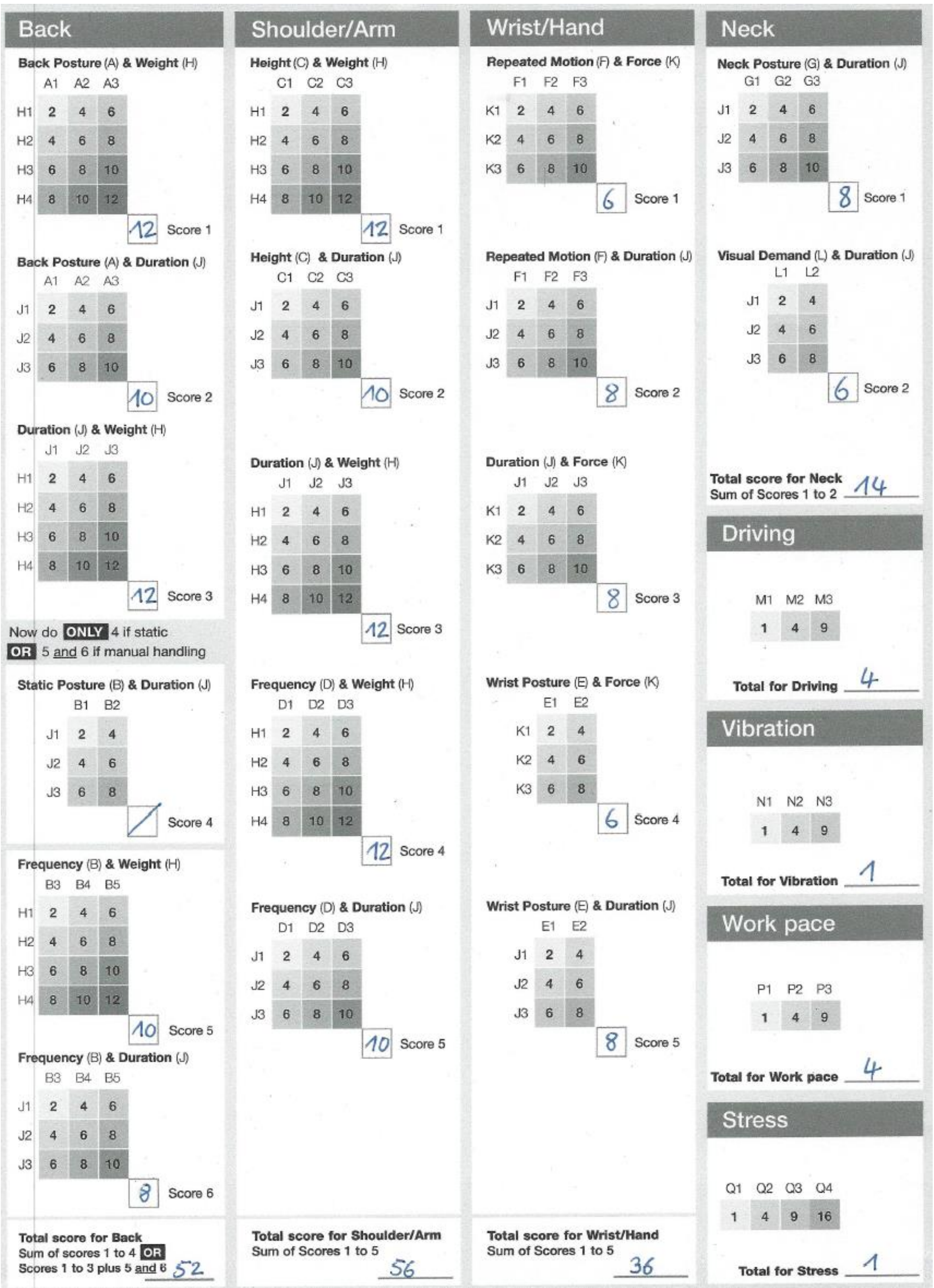
* *Additional details for L, P and Q if appropriate*

*** L**

*** P**

*** Q**

Figure A.14 First page of the conducted Quick Exposure Questionnaire for worker 2.



Back

Back Posture (A) & Weight (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 1

Back Posture (A) & Duration (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

10 Score 2

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 3

Now do **ONLY** 4 if static
OR 5 and 6 if manual handling

Static Posture (B) & Duration (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

/ Score 4

Frequency (B) & Weight (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

10 Score 5

Frequency (B) & Duration (J)

	B3	B4	B5
J1	2	4	6
J2	4	6	8
J3	6	8	10

8 Score 6

Total score for Back
Sum of scores 1 to 4 **OR** Scores 1 to 3 plus 5 and 6 52

Shoulder/Arm

Height (C) & Weight (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 1

Height (C) & Duration (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

10 Score 2

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 3

Frequency (D) & Weight (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 4

Frequency (D) & Duration (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

10 Score 5

Total score for Shoulder/Arm
Sum of Scores 1 to 5 56

Wrist/Hand

Repeated Motion (F) & Force (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

6 Score 1

Repeated Motion (F) & Duration (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

8 Score 2

Duration (J) & Force (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

8 Score 3

Wrist Posture (E) & Force (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

6 Score 4

Wrist Posture (E) & Duration (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

8 Score 5

Total score for Wrist/Hand
Sum of Scores 1 to 5 36

Neck

Neck Posture (G) & Duration (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

8 Score 1

Visual Demand (L) & Duration (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

6 Score 2

Total score for Neck
Sum of Scores 1 to 2 14

Driving

M1	M2	M3
1	4	9

Total for Driving 4

Vibration

N1	N2	N3
1	4	9

Total for Vibration 1

Work pace

P1	P2	P3
1	4	9

Total for Work pace 4

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress 1

Figure A.15 Second page of the conducted Quick Exposure Questionnaire for worker 2.

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

- A1 Almost neutral?
- A2 Moderately flexed or twisted or side bent?
- A3 [X] Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?

- B1 No
- B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

- B3 Infrequent (around 3 times per minute or less)?
- B4 [X] Frequent (around 8 times per minute)?
- B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

- C1 At or below waist height?
- C2 At about chest height?
- C3 [X] At or above shoulder height?

D Is the shoulder/arm movement

- D1 Infrequent (some intermittent movement)?
- D2 Frequent (regular movement with some pauses)?
- D3 [X] Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)

- E1 An almost straight wrist?
- E2 [X] A deviated or bent wrist?

F Are similar motion patterns repeated

- F1 10 times per minute or less?
- F2 [X] 11 to 20 times per minute?
- F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

- G1 No
- G2 [X] Yes, occasionally
- G3 Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

- H1 Light (5 kg or less)
- H2 Moderate (6 to 10 kg)
- H3 Heavy (11 to 20kg)
- H4 [X] Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

- J1 [X] Less than 2 hours
- J2 2 to 4 hours
- J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

- K1 Low (e.g. less than 1 kg)
- K2 Medium (e.g. 1 to 4 kg)
- K3 [X] High (e.g. more than 4 kg)

L Is the visual demand of this task

- L1 [X] Low (almost no need to view fine details)?
- *L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for

- M1 Less than one hour per day or Never?
- M2 [X] Between 1 and 4 hours per day?
- M3 More than 4 hours per day?

N At work do you use vibrating tools for

- N1 [X] Less than one hour per day or Never?
- N2 Between 1 and 4 hours per day?
- N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?

- P1 Never
- P2 [X] Sometimes
- *P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job

- Q1 Not at all stressful?
- Q2 [X] Mildly stressful?
- *Q3 Moderately stressful?
- *Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

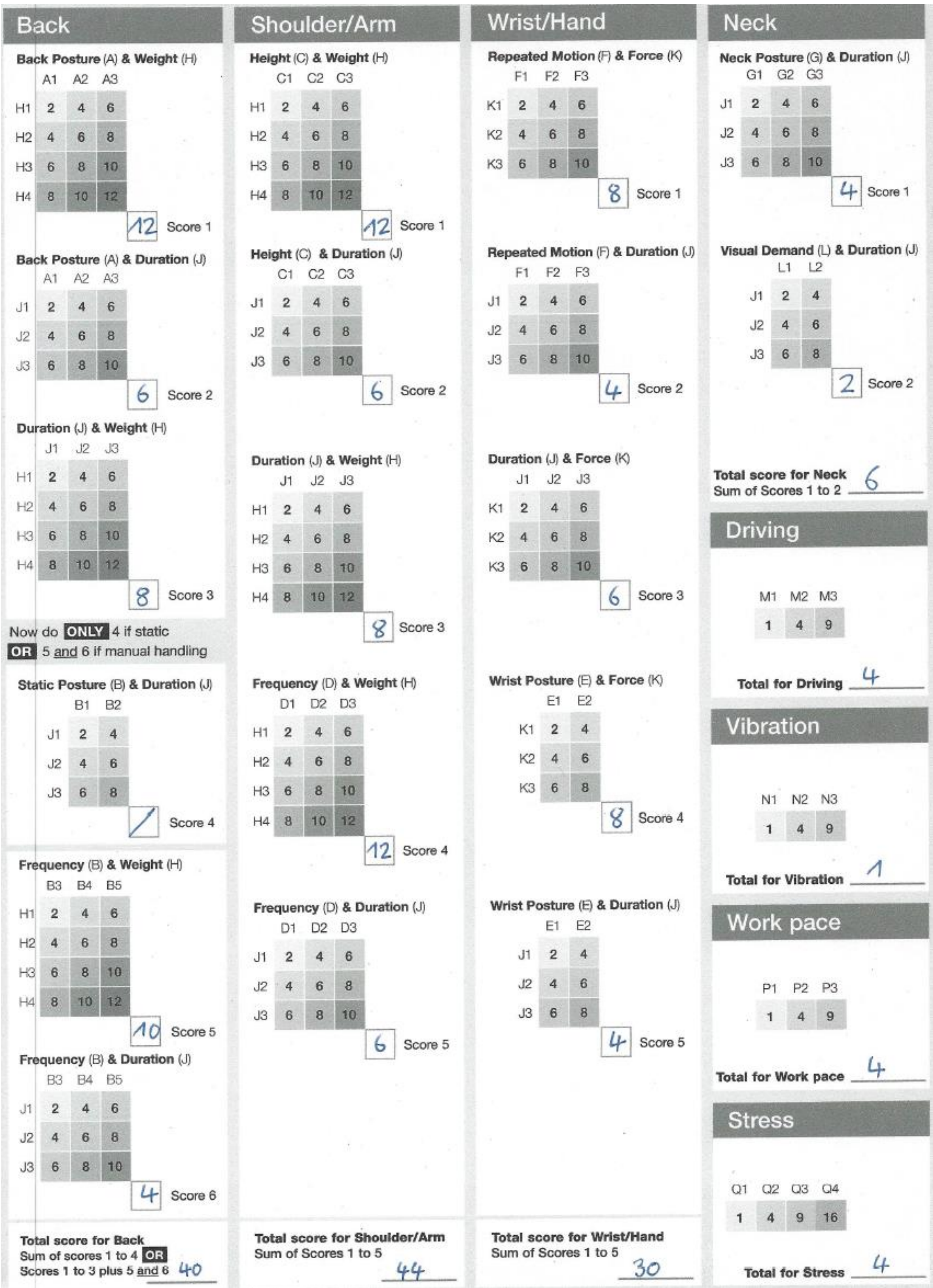
* *Additional details for L, P and Q if appropriate*

*L

*P

*Q

Figure A.16 First page of the conducted Quick Exposure Questionnaire for worker 3.



Back

Back Posture (A) & Weight (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1: 12

Back Posture (A) & Duration (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2: 6

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3: 8

Now do **ONLY** 4 if static
OR 5 and 6 if manual handling

Static Posture (B) & Duration (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

Score 4: /

Frequency (B) & Weight (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 5: 10

Frequency (B) & Duration (J)

	B3	B4	B5
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 6: 4

Total score for Back
Sum of scores 1 to 4 **OR**
Scores 1 to 3 plus 5 and 6: 40

Shoulder/Arm

Height (C) & Weight (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1: 12

Height (C) & Duration (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2: 6

Duration (J) & Weight (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3: 8

Frequency (D) & Weight (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 4: 12

Frequency (D) & Duration (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 5: 6

Total score for Shoulder/Arm
Sum of Scores 1 to 5: 44

Wrist/Hand

Repeated Motion (F) & Force (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 1: 8

Repeated Motion (F) & Duration (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2: 4

Duration (J) & Force (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 3: 6

Wrist Posture (E) & Force (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

Score 4: 8

Wrist Posture (E) & Duration (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

Score 5: 4

Total score for Wrist/Hand
Sum of Scores 1 to 5: 30

Neck

Neck Posture (G) & Duration (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 1: 4

Visual Demand (L) & Duration (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

Score 2: 2

Total score for Neck
Sum of Scores 1 to 2: 6

Driving

M1	M2	M3
1	4	9

Total for Driving 4

Vibration

N1	N2	N3
1	4	9

Total for Vibration 1

Work pace

P1	P2	P3
1	4	9

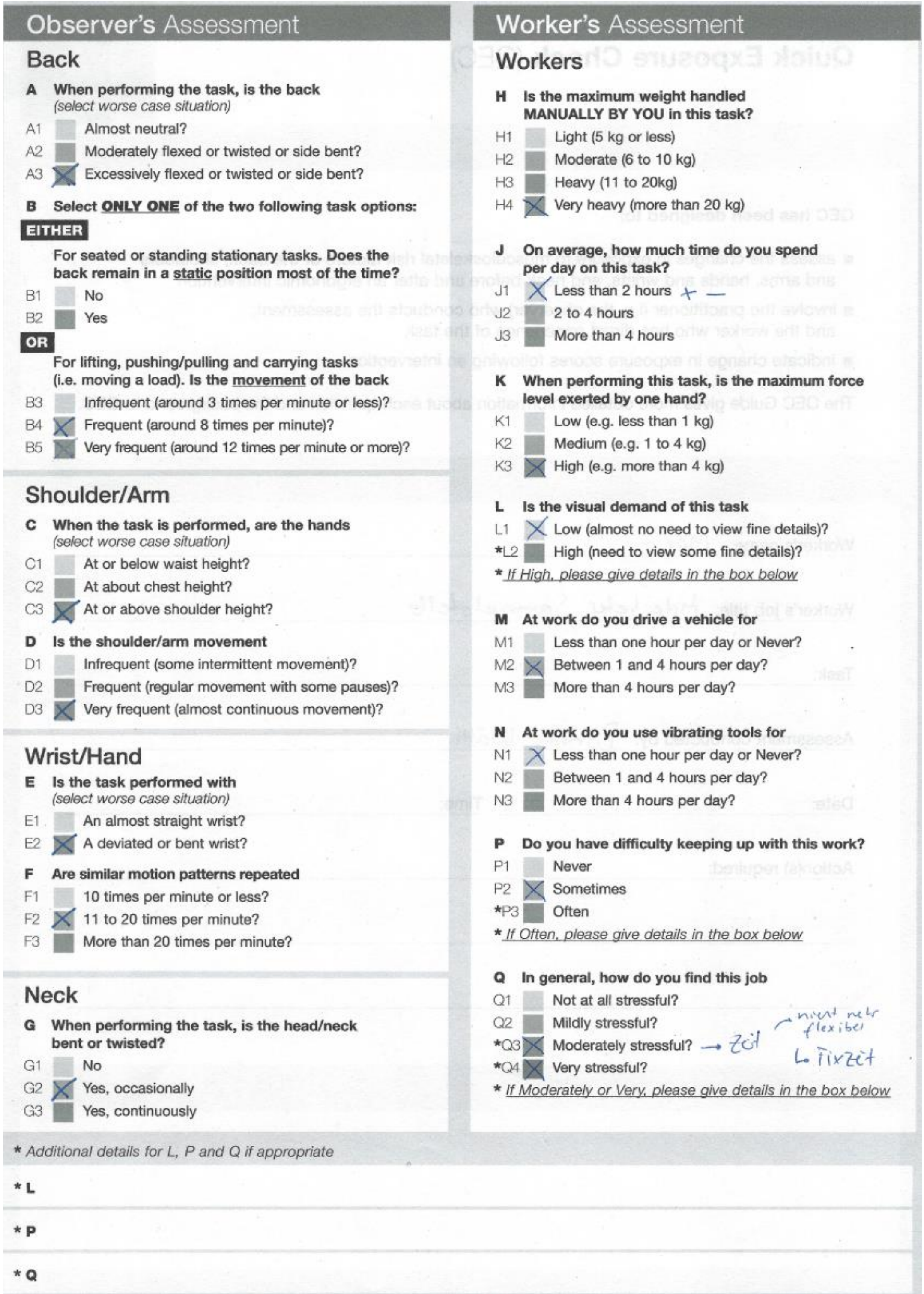
Total for Work pace 4

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress 4

Figure A.17 Second page of the conducted Quick Exposure Questionnaire for worker 3.



Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

- A1 [ ] Almost neutral?
- A2 [ ] Moderately flexed or twisted or side bent?
- A3 [X] Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?

- B1 [ ] No
- B2 [ ] Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

- B3 [ ] Infrequent (around 3 times per minute or less)?
- B4 [X] Frequent (around 8 times per minute)?
- B5 [X] Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

- C1 [ ] At or below waist height?
- C2 [ ] At about chest height?
- C3 [X] At or above shoulder height?

D Is the shoulder/arm movement

- D1 [ ] Infrequent (some intermittent movement)?
- D2 [ ] Frequent (regular movement with some pauses)?
- D3 [X] Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)

- E1 [ ] An almost straight wrist?
- E2 [X] A deviated or bent wrist?

F Are similar motion patterns repeated

- F1 [ ] 10 times per minute or less?
- F2 [X] 11 to 20 times per minute?
- F3 [ ] More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

- G1 [ ] No
- G2 [X] Yes, occasionally
- G3 [ ] Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

- H1 [ ] Light (5 kg or less)
- H2 [ ] Moderate (6 to 10 kg)
- H3 [ ] Heavy (11 to 20kg)
- H4 [X] Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

- J1 [X] Less than 2 hours + —
- J2 [ ] 2 to 4 hours
- J3 [ ] More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

- K1 [ ] Low (e.g. less than 1 kg)
- K2 [ ] Medium (e.g. 1 to 4 kg)
- K3 [X] High (e.g. more than 4 kg)

L Is the visual demand of this task

- L1 [X] Low (almost no need to view fine details)?
- *L2 [ ] High (need to view some fine details)?

** If High, please give details in the box below*

M At work do you drive a vehicle for

- M1 [ ] Less than one hour per day or Never?
- M2 [X] Between 1 and 4 hours per day?
- M3 [ ] More than 4 hours per day?

N At work do you use vibrating tools for

- N1 [X] Less than one hour per day or Never?
- N2 [ ] Between 1 and 4 hours per day?
- N3 [ ] More than 4 hours per day?

P Do you have difficulty keeping up with this work?

- P1 [ ] Never
- P2 [X] Sometimes
- *P3 [ ] Often

** If Often, please give details in the box below*

Q In general, how do you find this job

- Q1 [ ] Not at all stressful?
- Q2 [ ] Mildly stressful?
- *Q3 [X] Moderately stressful? → Zeit
- *Q4 [X] Very stressful?

nicht mehr flexibel
L Fixzeit

** If Moderately or Very, please give details in the box below*

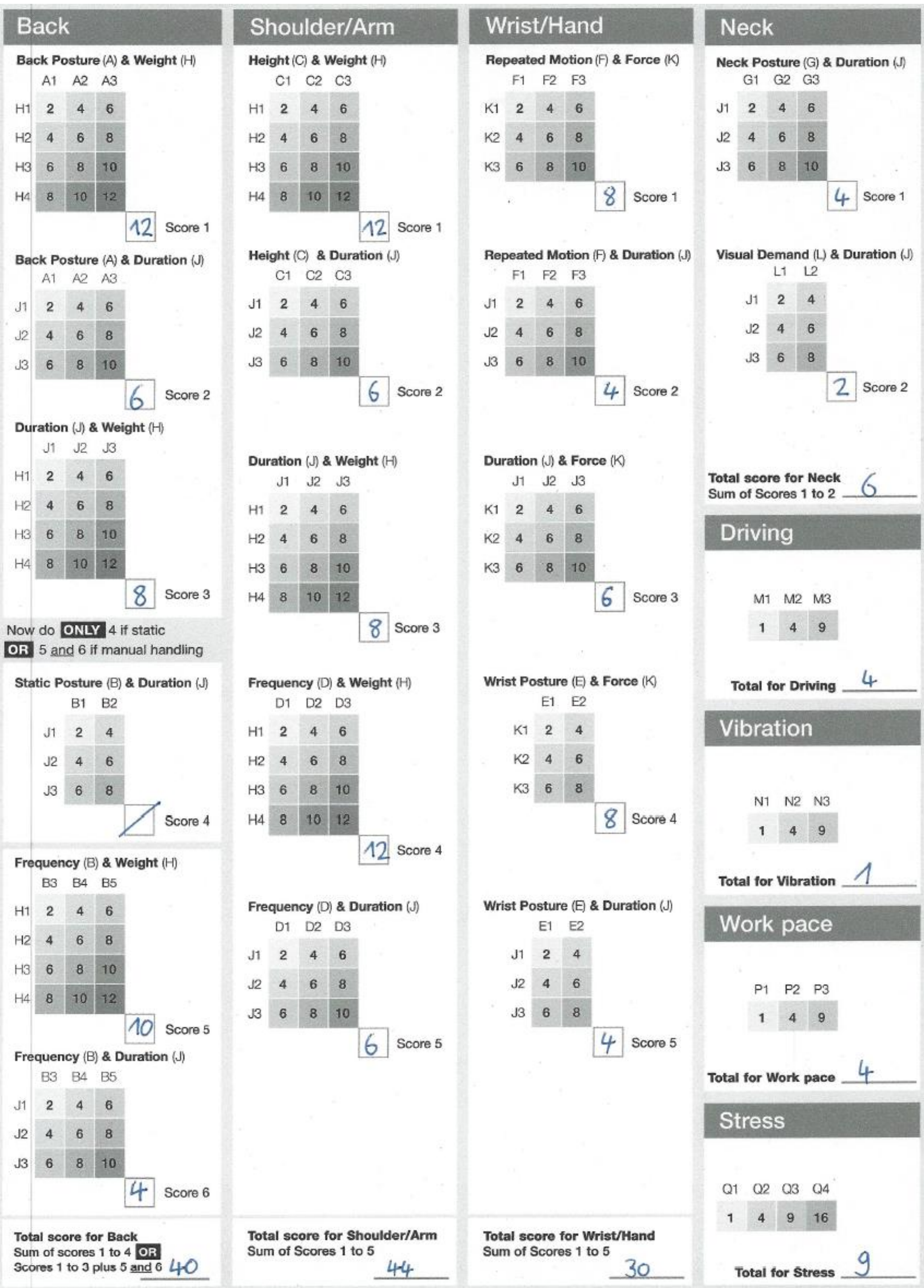
** Additional details for L, P and Q if appropriate*

* L

* P

* Q

Figure A.18 First page of the conducted Quick Exposure Questionnaire for worker 4.



Back

Back Posture (A) **& Weight** (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 1

Back Posture (A) **& Duration** (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

6 Score 2

Duration (J) **& Weight** (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

8 Score 3

Now do **ONLY** 4 if static
OR 5 and 6 if manual handling

Static Posture (B) **& Duration** (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

/ Score 4

Frequency (B) **& Weight** (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

10 Score 5

Frequency (B) **& Duration** (J)

	B3	B4	B5
J1	2	4	6
J2	4	6	8
J3	6	8	10

4 Score 6

Total score for Back
Sum of scores 1 to 4 **OR**
Scores 1 to 3 plus 5 and 6 40

Shoulder/Arm

Height (C) **& Weight** (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 1

Height (C) **& Duration** (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

6 Score 2

Duration (J) **& Weight** (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

8 Score 3

Frequency (D) **& Weight** (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

12 Score 4

Frequency (D) **& Duration** (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

6 Score 5

Total score for Shoulder/Arm
Sum of Scores 1 to 5 44

Wrist/Hand

Repeated Motion (F) **& Force** (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

8 Score 1

Repeated Motion (F) **& Duration** (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

4 Score 2

Duration (J) **& Force** (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

6 Score 3

Wrist Posture (E) **& Force** (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

8 Score 4

Wrist Posture (E) **& Duration** (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

4 Score 5

Total score for Wrist/Hand
Sum of Scores 1 to 5 30

Neck

Neck Posture (G) **& Duration** (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

4 Score 1

Visual Demand (L) **& Duration** (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

2 Score 2

Total score for Neck
Sum of Scores 1 to 2 6

Driving

M1	M2	M3
1	4	9

Total for Driving 4

Vibration

N1	N2	N3
1	4	9

Total for Vibration 1

Work pace

P1	P2	P3
1	4	9

Total for Work pace 4

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress 9

Figure A.19 Second page of the conducted Quick Exposure Questionnaire for worker 4.

A.2.2 Rapid Entire Body Assessment

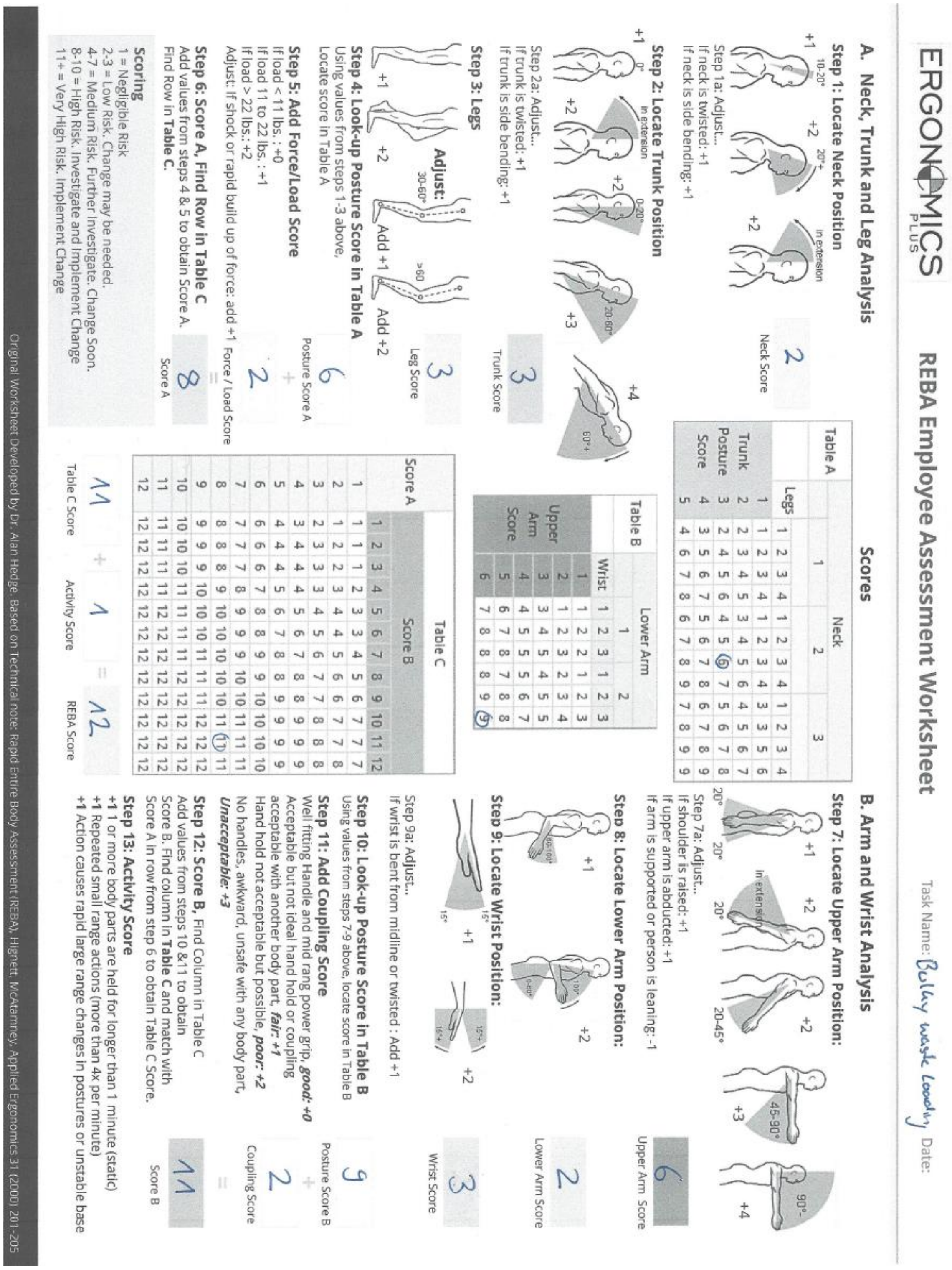


Figure A.20 Conducted REBA risk assessment method.

A.2.3 Rapid Upper Limb Assessment

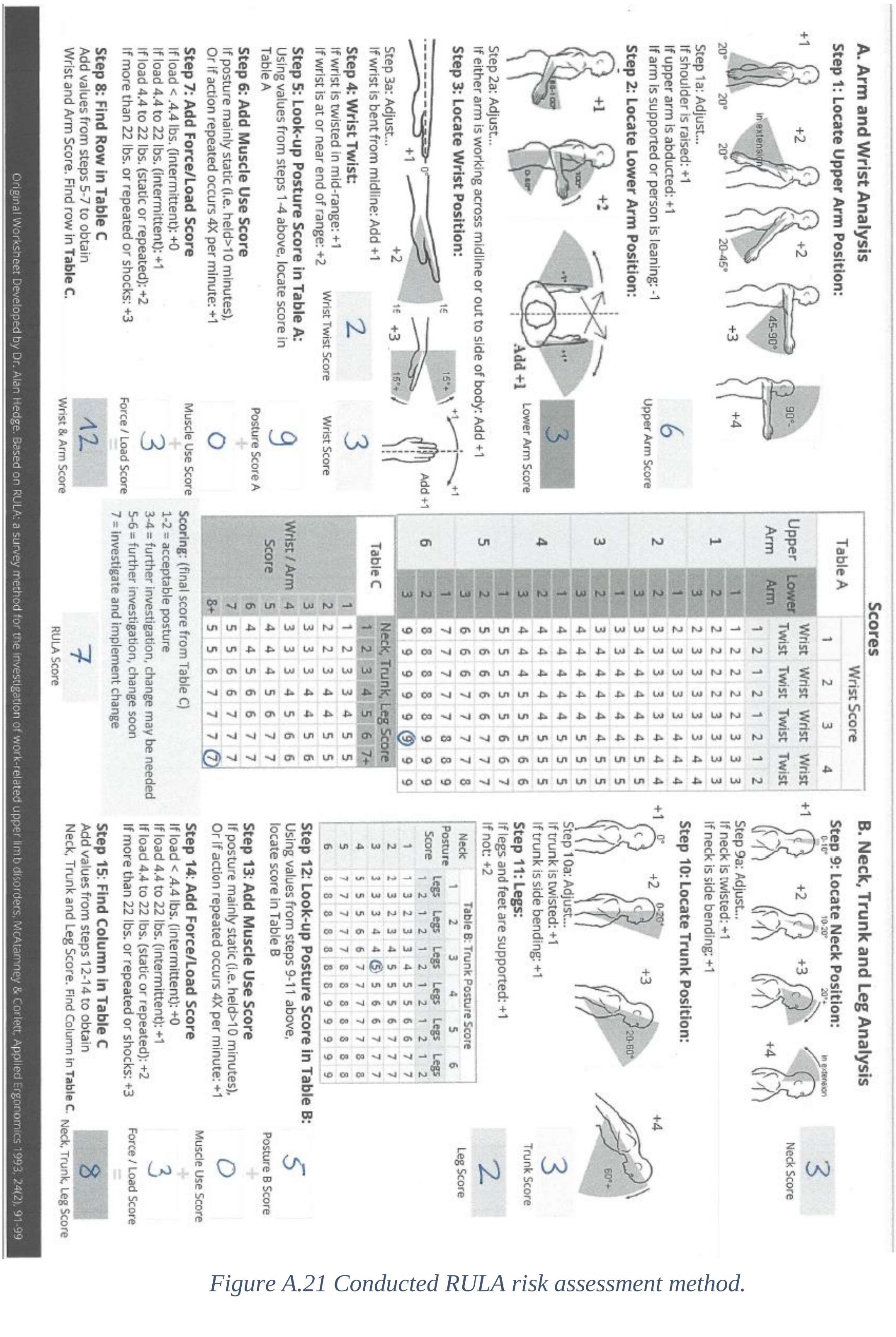
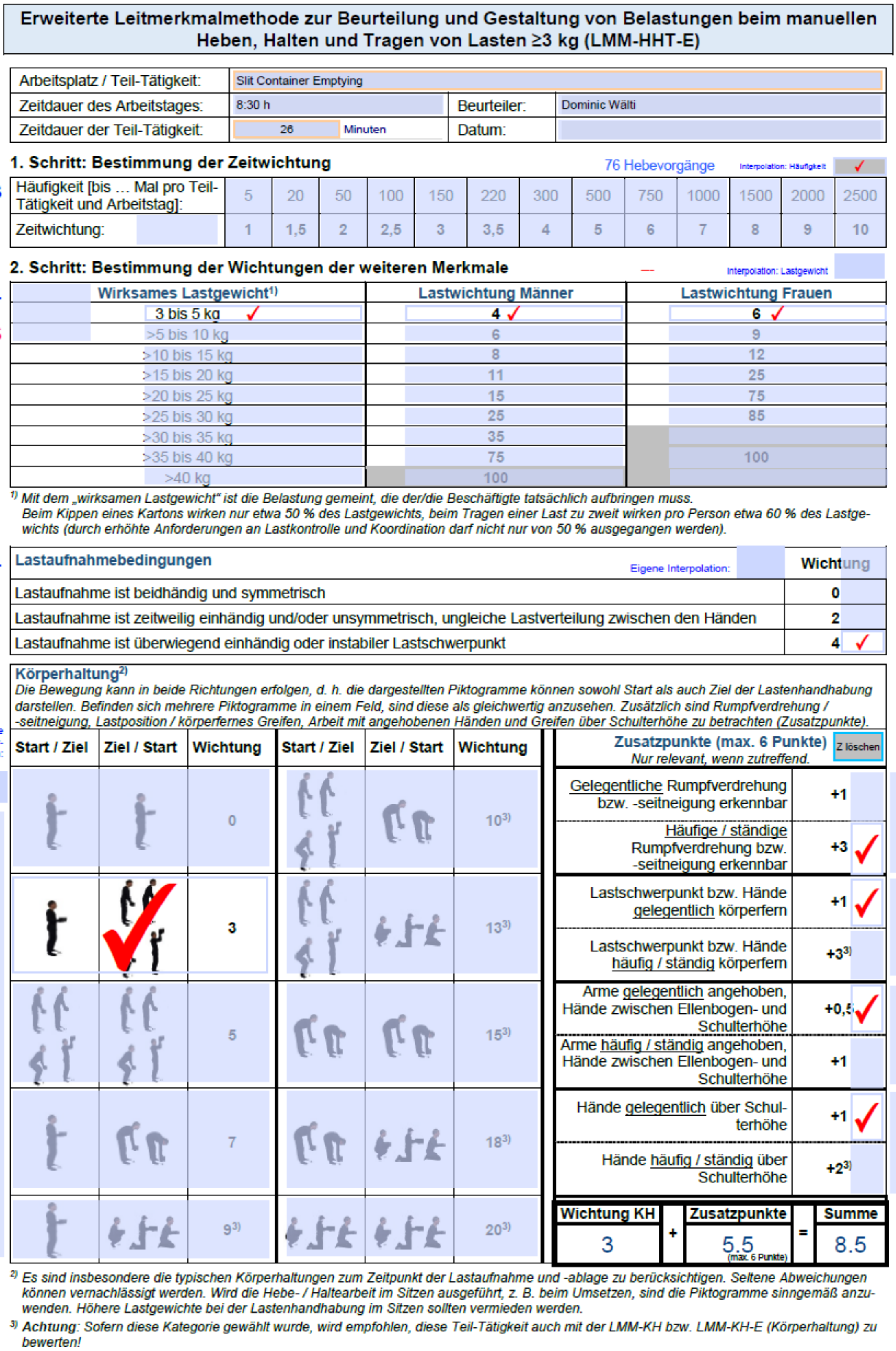


Figure A.21 Conducted RULA risk assessment method.

A.2.4 Key Indicator Methods



Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen beim manuellen Heben, Halten und Tragen von Lasten ≥3 kg (LMM-HHT-E)

Arbeitsplatz / Teil-Tätigkeit:	Slit Container Emptying		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	26 Minuten	Datum:	

1. Schritt: Bestimmung der Zeitwichtung — 76 Hebevorgänge — Interpolation: Häufigkeit ✓

2.3													
Häufigkeit [bis … Mal pro Teil-Tätigkeit und Arbeitstag]:	5	20	50	100	150	220	300	500	750	1000	1500	2000	2500
Zeitwichtung:	1	1,5	2	2,5	3	3,5	4	5	6	7	8	9	10

2. Schritt: Bestimmung der Wichtungen der weiteren Merkmale — Interpolation: Lastgewicht

4 / 6

Wirksames Lastgewicht[1]	Lastwichtung Männer	Lastwichtung Frauen
3 bis 5 kg ✓	4 ✓	6 ✓
>5 bis 10 kg	6	9
>10 bis 15 kg	8	12
>15 bis 20 kg	11	25
>20 bis 25 kg	15	75
>25 bis 30 kg	25	85
>30 bis 35 kg	35	100
>35 bis 40 kg	75	
>40 kg	100	

[1] *Mit dem „wirksamen Lastgewicht" ist die Belastung gemeint, die der/die Beschäftigte tatsächlich aufbringen muss. Beim Kippen eines Kartons wirken nur etwa 50 % des Lastgewichts, beim Tragen einer Last zu zweit wirken pro Person etwa 60 % des Lastgewichts (durch erhöhte Anforderungen an Lastkontrolle und Koordination darf nicht nur von 50 % ausgegangen werden).*

4

Lastaufnahmebedingungen (Eigene Interpolation:)	Wichtung
Lastaufnahme ist beidhändig und symmetrisch	0
Lastaufnahme ist zeitweilig einhändig und/oder unsymmetrisch, ungleiche Lastverteilung zwischen den Händen	2
Lastaufnahme ist überwiegend einhändig oder instabiler Lastschwerpunkt	4 ✓

Körperhaltung[2]

Die Bewegung kann in beide Richtungen erfolgen, d. h. die dargestellten Piktogramme können sowohl Start als auch Ziel der Lastenhandhabung darstellen. Befinden sich mehrere Piktogramme in einem Feld, sind diese als gleichwertig anzusehen. Zusätzlich sind Rumpfverdrehung / -seitneigung, Lastposition / körperfernes Greifen, Arbeit mit angehobenen Händen und Greifen über Schulterhöhe zu betrachten (Zusatzpunkte).

Eigene Interpolation:

Start / Ziel	Ziel / Start	Wichtung	Start / Ziel	Ziel / Start	Wichtung
		0			10[3]
	✓	3			13[3]
		5			15[3]
		7			18[3]
		9[3]			20[3]

Zusatzpunkte (max. 6 Punkte) — *Nur relevant, wenn zutreffend.* — Z löschen

Gelegentliche Rumpfverdrehung bzw. -seitneigung erkennbar	+1	
Häufige / ständige Rumpfverdrehung bzw. -seitneigung erkennbar	+3	✓
Lastschwerpunkt bzw. Hände gelegentlich körperfern	+1	✓
Lastschwerpunkt bzw. Hände häufig / ständig körperfern	+3[3]	
Arme gelegentlich angehoben, Hände zwischen Ellenbogen- und Schulterhöhe	+0,5	✓
Arme häufig / ständig angehoben, Hände zwischen Ellenbogen- und Schulterhöhe	+1	
Hände gelegentlich über Schulterhöhe	+1	✓
Hände häufig / ständig über Schulterhöhe	+2[3]	

Wichtung KH		Zusatzpunkte		Summe
3	+	5.5 (max. 6 Punkte)	=	8.5

[2] *Es sind insbesondere die typischen Körperhaltungen zum Zeitpunkt der Lastaufnahme und -ablage zu berücksichtigen. Seltene Abweichungen können vernachlässigt werden. Wird die Hebe- / Haltearbeit im Sitzen ausgeführt, z. B. beim Umsetzen, sind die Piktogramme sinngemäß anzuwenden. Höhere Lastgewichte bei der Lastenhandhabung im Sitzen sollten vermieden werden.*

[3] ***Achtung**: Sofern diese Kategorie gewählt wurde, wird empfohlen, diese Teil-Tätigkeit auch mit der LMM-KH bzw. LMM-KH-E (Körperhaltung) zu bewerten!*

Figure A.22 First page of the conducted KIM risk assessment method regarding the slit-container emptying activity.

Ungünstige Ausführungsbedingungen (nur angeben, wenn zutreffend) *In den Tabellen nicht genannte Merkmale sind sinngemäß zu berücksichtigen.* *Seltene Abweichungen sind vernachlässigbar.*		**Zwi-schen-wichtung ZW**		**∑ ZW**
Hand-/Armstellung-bewegung:	Gelegentlich am Ende der Beweglichkeitsbereiche	1	✓	4
	Häufig / ständig am Ende der Beweglichkeitsbereiche	2		
Kraftübertragung/-einleitung eingeschränkt: Lasten schlecht greifbar / erhöhte Haltekräfte erforderlich / keine gestalteten Griffe / Arbeitshandschuhe		1		
Kraftübertragung/-einleitung erheblich behindert: Lasten kaum greifbar / schmierig, weich, scharfkantig / keine oder ungeeignete Griffe / Arbeitshandschuhe		2		
Umgebungsbedingungen eingeschränkt: Ungünstige Witterungsbedingungen und/oder Belastungen durch Hitze, Zugluft, Kälte, Nässe		1	✓	
Räumliche Bedingungen eingeschränkt: Zu kleine Arbeitsfläche unter 1,5 m², Boden ist mäßig verschmutzt, etwas uneben, leichte Neigung bis 5°, leicht eingeschränkte Standsicherheit, Last ist genau zu positionieren		1		
Räumliche Bedingungen ungünstig: Stark eingeschränkte Bewegungsfreiheit oder Bewegungsraum hat zu geringe Höhe, Arbeiten auf engem Raum, Boden ist stark verschmutzt, uneben oder grob gepflastert, Stufen / Schlaglöcher, stärkere Neigung 5–10°, eingeschränkte Standsicherheit, Last ist sehr genau zu positionieren		2[4]		
Kleidung: Zusätzliche Belastung durch beeinträchtigende Kleidung oder Ausrüstung (z. B. Tragen schwerer Regenjacken, Ganzkörperschutzanzügen, Atemschutzgeräten, Werkzeuggürteln o. ä.)		1		
Erschwernis durch Halten / Tragen: Die Last ist zwischen >5 und 10 Sekunden zu halten oder über eine Strecke zwischen >2 m und 5 m zu tragen.		2	✓	
Deutliche Erschwernis durch Halten / Tragen: Die Last >10 Sekunden zu halten oder über eine Strecke >5 m zu tragen.		5[4]		
Keine: Es liegen keine ungünstigen Ausführungsbedingen vor.		0		

[4] *Achtung: Sofern beim Tragen von Lasten ungünstige räumliche Bedingungen vorliegen oder die Last über Strecken >10 m zu tragen ist, ist diese Teil-Tätigkeit mit der LMM-KB bzw. LMM-KB-E zu bewerten!*

Arbeitsorganisation / Zeitliche Verteilung Eigene Interpolation:	**Wichtung**	2
Gut: Häufig Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / ohne enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	0	
Eingeschränkt: Selten Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / gelegentlich enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	2	✓
Ungünstig: Kein/kaum Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / häufig enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag mit zeitweise hohen Belastungsspitzen.	4	

3. Schritt: Bewertung und Beurteilung

	M	W
Wirksames Lastgewicht	4	6
Lastaufnahmebedingungen +	4	
Summe Körperhaltung +	8.5	
Ungünstige Ausführungsbedingungen (∑ ZW) +	4	
Arbeitsorganisation / Zeitliche Verteilung +	2	

2.3 **Zeitwichtung**	x	**Summe Merkmalswichtungen:** M	W	=	**Ergebnisse** M	W
		22.5	24.5	=	51	56

Anhand des errechneten Punktwertes und der folgenden Tabelle kann eine grobe Beurteilung vorgenommen werden:

Risiko	**Risikobereich**		**Belastungs-höhe**[*]	**a) Wahrscheinlichkeit körperlicher Überbeanspruchung** **b) Mögliche gesundheitliche Folgen**	**Maßnahmen**
	1	<20 Punkte	gering	a) Körperliche Überbeanspruchung ist unwahrscheinlich b) Gesundheitsgefährdung nicht zu erwarten	Keine
	2	20 – <50 Punkte	mäßig erhöht	a) Körperliche Überbeanspruchung ist bei vermindert belastbaren Personen möglich. b) Ermüdung, geringgradige Anpassungsbeschwerden, die in der Freizeit kompensiert werden können	Für vermindert belastbare Personen sind Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sinnvoll.
M, W	3	50 – <100 Punkte	wesentlich erhöht	a) Körperliche Überbeanspruchung ist auch für normal belastbare Personen möglich b) Beschwerden (Schmerzen) ggf. mit Funktionsstörungen, meistens reversibel, ohne morphologische Manifestation	Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sind zu prüfen.
	4	≥100 Punkte	hoch	a) Körperliche Überbeanspruchung ist wahrscheinlich. b) Stärker ausgeprägte Beschwerden und / oder Funktionsstörungen, Strukturschäden mit Krankheitswert	Maßnahmen zur Gestaltung sind erforderlich. Sonstige Präventionsmaßnahmen sind zu prüfen.

[*] *Die Grenzen zwischen den Risikobereichen sind aufgrund der individuellen Arbeitstechniken und Leistungsvoraussetzungen fließend. Damit darf die Einstufung nur als Orientierungshilfe verstanden werden. Grundsätzlich ist davon auszugehen, dass mit steigenden Punktwerten die Wahrscheinlichkeit einer körperlichen Überbeanspruchung zunimmt.*

Figure A.23 Second page of the conducted KIM risk assessment method regarding the slit-container emptying activity.

Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen beim manuellen Heben, Halten und Tragen von Lasten ≥3 kg (LMM-HHT-E)

Arbeitsplatz / Teil-Tätigkeit:	Slit Container Emptying		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	26	Datum:	

Beschreibung der Teil-Tätigkeit

For the calculation of the time weighting factor:
Since in average there are two slit-containers at each collection site and the time measured corresponds to the total amount of time spent emptying all slit-containers, one must consider that in the calculation of the time weighting factor, namely in the determination of the "Häufigkeit".

"Häufigkeit":

Average time spent per site collection on emptying slit-containers = 41.6 s (from Excel Sheet)

Since in average there are 2 slit-containers present at each collection site:

--> Average time spent per site collection on emptying one slit-container = 20.8 s

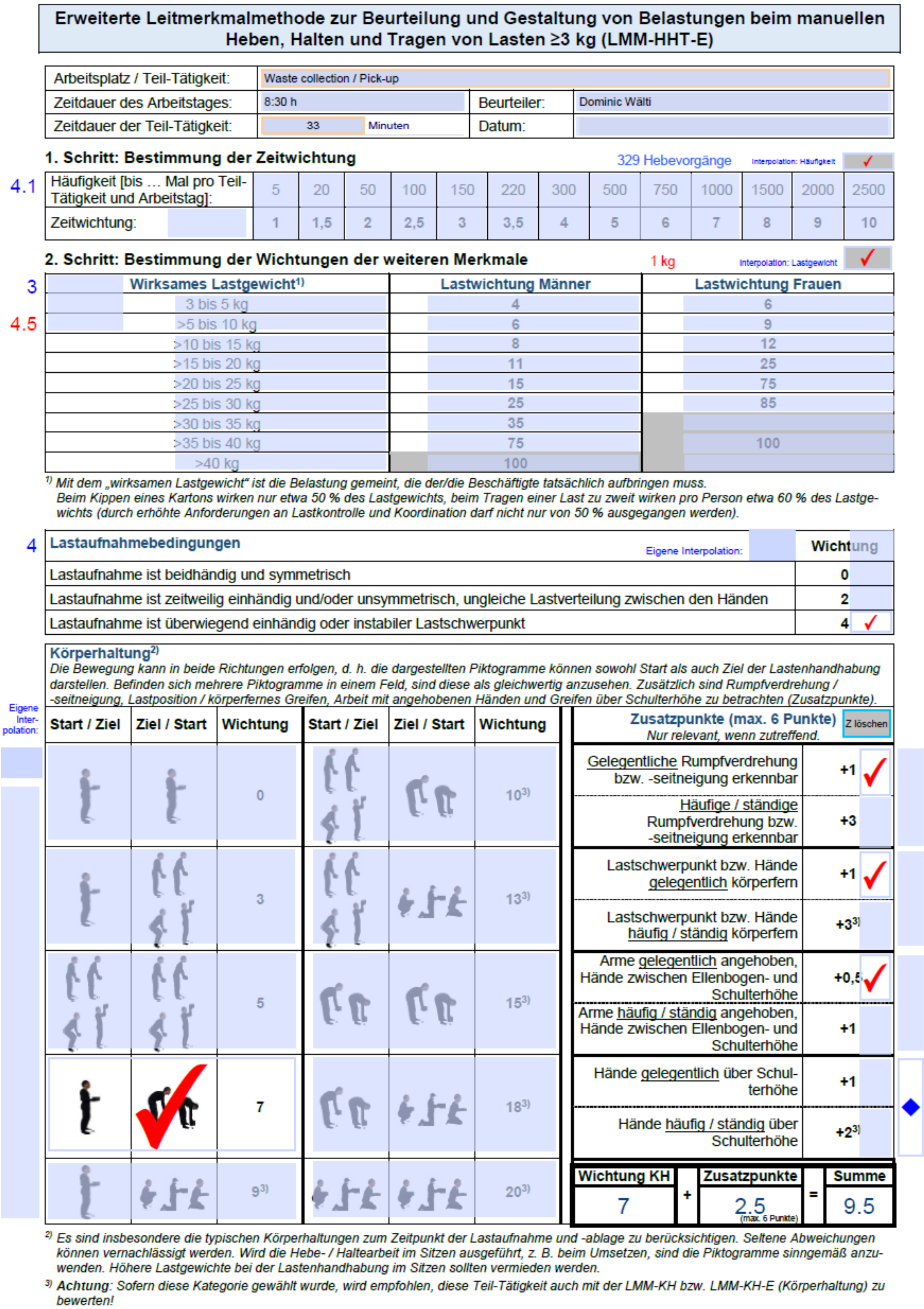
Therefore,

Häufigkeit = Overall average time spent per day / Average time spent emptying one slit-container

= 1583 s / 20.8 s

= 76

Figure A.24 Third page of the conducted KIM risk assessment method regarding the slit-container emptying activity.



Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen beim manuellen Heben, Halten und Tragen von Lasten ≥3 kg (LMM-HHT-E)

Arbeitsplatz / Teil-Tätigkeit:	Waste collection / Pick-up		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	33 Minuten	Datum:	

1. Schritt: Bestimmung der Zeitwichtung 329 Hebevorgänge Interpolation: Häufigkeit ✓

4.1

Häufigkeit [bis … Mal pro Teil-Tätigkeit und Arbeitstag]:	5	20	50	100	150	220	300	500	750	1000	1500	2000	2500
Zeitwichtung:	1	1,5	2	2,5	3	3,5	4	5	6	7	8	9	10

2. Schritt: Bestimmung der Wichtungen der weiteren Merkmale 1 kg Interpolation: Lastgewicht ✓

3

4.5

Wirksames Lastgewicht[1]	Lastwichtung Männer	Lastwichtung Frauen
3 bis 5 kg	4	6
>5 bis 10 kg	6	9
>10 bis 15 kg	8	12
>15 bis 20 kg	11	25
>20 bis 25 kg	15	75
>25 bis 30 kg	25	85
>30 bis 35 kg	35	
>35 bis 40 kg	75	100
>40 kg	100	

[1] *Mit dem „wirksamen Lastgewicht" ist die Belastung gemeint, die der/die Beschäftigte tatsächlich aufbringen muss. Beim Kippen eines Kartons wirken nur etwa 50 % des Lastgewichts, beim Tragen einer Last zu zweit wirken pro Person etwa 60 % des Lastgewichts (durch erhöhte Anforderungen an Lastkontrolle und Koordination darf nicht nur von 50 % ausgegangen werden).*

4

Lastaufnahmebedingungen (Eigene Interpolation:)	Wichtung
Lastaufnahme ist beidhändig und symmetrisch	0
Lastaufnahme ist zeitweilig einhändig und/oder unsymmetrisch, ungleiche Lastverteilung zwischen den Händen	2
Lastaufnahme ist überwiegend einhändig oder instabiler Lastschwerpunkt	4 ✓

Körperhaltung[2]
Die Bewegung kann in beide Richtungen erfolgen, d. h. die dargestellten Piktogramme können sowohl Start als auch Ziel der Lastenhandhabung darstellen. Befinden sich mehrere Piktogramme in einem Feld, sind diese als gleichwertig anzusehen. Zusätzlich sind Rumpfverdrehung / -seitneigung, Lastposition / körperfernes Greifen, Arbeit mit angehobenen Händen und Greifen über Schulterhöhe zu betrachten (Zusatzpunkte).

Eigene Inter-polation:

Start / Ziel	Ziel / Start	Wichtung	Start / Ziel	Ziel / Start	Wichtung
		0			10[3]
		3			13[3]
		5			15[3]
	✓	7			18[3]
		9[3]			20[3]

Zusatzpunkte (max. 6 Punkte) Z löschen
Nur relevant, wenn zutreffend.

Gelegentliche Rumpfverdrehung bzw. -seitneigung erkennbar	+1	✓
Häufige / ständige Rumpfverdrehung bzw. -seitneigung erkennbar	+3	
Lastschwerpunkt bzw. Hände gelegentlich körperfern	+1	✓
Lastschwerpunkt bzw. Hände häufig / ständig körperfern	+3[3]	
Arme gelegentlich angehoben, Hände zwischen Ellenbogen- und Schulterhöhe	+0,5	✓
Arme häufig / ständig angehoben, Hände zwischen Ellenbogen- und Schulterhöhe	+1	
Hände gelegentlich über Schulterhöhe	+1	
Hände häufig / ständig über Schulterhöhe	+2[3]	

Wichtung KH		Zusatzpunkte		Summe
7	+	2.5 (max. 6 Punkte)	=	9.5

[2] *Es sind insbesondere die typischen Körperhaltungen zum Zeitpunkt der Lastaufnahme und -ablage zu berücksichtigen. Seltene Abweichungen können vernachlässigt werden. Wird die Hebe- / Haltearbeit im Sitzen ausgeführt, z. B. beim Umsetzen, sind die Piktogramme sinngemäß anzuwenden. Höhere Lastgewichte bei der Lastenhandhabung im Sitzen sollten vermieden werden.*

[3] ***Achtung**: Sofern diese Kategorie gewählt wurde, wird empfohlen, diese Teil-Tätigkeit auch mit der LMM-KH bzw. LMM-KH-E (Körperhaltung) zu bewerten!*

Figure A.25 First page of the conducted KIM risk assessment method regarding the collection of small waste materials activity.

Ungünstige Ausführungsbedingungen (nur angeben, wenn zutreffend) *In den Tabellen nicht genannte Merkmale sind sinngemäß zu berücksichtigen.* *Seltene Abweichungen sind vernachlässigbar.*		**Zwi-schen-wichtung ZW**		**∑ ZW**
Hand-/Armstellung-bewegung: 	Gelegentlich am Ende der Beweglichkeitsbereiche	1	✓	2
	Häufig / ständig am Ende der Beweglichkeitsbereiche	2		
Kraftübertragung/-einleitung eingeschränkt: Lasten schlecht greifbar / erhöhte Haltekräfte erforderlich / keine gestalteten Griffe / Arbeitshandschuhe		1		
Kraftübertragung/-einleitung erheblich behindert: Lasten kaum greifbar / schmierig, weich, scharfkantig / keine oder ungeeignete Griffe / Arbeitshandschuhe		2		
Umgebungsbedingungen eingeschränkt: Ungünstige Witterungsbedingungen und/oder Belastungen durch Hitze, Zugluft, Kälte, Nässe		1	✓	
Räumliche Bedingungen eingeschränkt: Zu kleine Arbeitsfläche unter 1,5 m², Boden ist mäßig verschmutzt, etwas uneben, leichte Neigung bis 5°, leicht eingeschränkte Standsicherheit, Last ist genau zu positionieren		1		
Räumliche Bedingungen ungünstig: Stark eingeschränkte Bewegungsfreiheit oder Bewegungsraum hat zu geringe Höhe, Arbeiten auf engem Raum, Boden ist stark verschmutzt, uneben oder grob gepflastert, Stufen / Schlaglöcher, stärkere Neigung 5–10°, eingeschränkte Standsicherheit, Last ist sehr genau zu positionieren		2[4)]		
Kleidung: Zusätzliche Belastung durch beeinträchtigende Kleidung oder Ausrüstung (z. B. Tragen schwerer Regenjacken, Ganzkörperschutzanzügen, Atemschutzgeräten, Werkzeuggürteln o. ä.)		1		
Erschwernis durch Halten / Tragen: Die Last ist zwischen >5 und 10 Sekunden zu halten oder über eine Strecke zwischen >2 m und 5 m zu tragen.		2		
Deutliche Erschwernis durch Halten / Tragen: Die Last >10 Sekunden zu halten oder über eine Strecke >5 m zu tragen.		5[4)]		
Keine: Es liegen keine ungünstigen Ausführungsbedingungen vor.		0		

[4)] *Achtung: Sofern beim Tragen von Lasten ungünstige räumliche Bedingungen vorliegen oder die Last über Strecken >10 m zu tragen ist, ist diese Teil-Tätigkeit mit der LMM-KB bzw. LMM-KB-E zu bewerten!*

Arbeitsorganisation / Zeitliche Verteilung Eigene Interpolation:	**Wichtung**		2
Gut: Häufig Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / ohne enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	0		
Eingeschränkt: Selten Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / gelegentlich enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	2	✓	
Ungünstig: Kein/kaum Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / häufig enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag mit zeitweise hohen Belastungsspitzen.	4		

3. Schritt: Bewertung und Beurteilung

		M	W
Wirksames Lastgewicht		3	4.5
Lastaufnahmebedingungen	+	4	
Summe Körperhaltung	+	9.5	
Ungünstige Ausführungsbedingungen (∑ ZW)	+	2	
Arbeitsorganisation / Zeitliche Verteilung	+	2	

			M	W		**Ergebnisse** M	**Ergebnisse** W
4.1 **Zeitwichtung**	x	**Summe Merkmalswichtungen:**	20.5	22	=	84	90

Anhand des errechneten Punktwertes und der folgenden Tabelle kann eine grobe Beurteilung vorgenommen werden:					
Risiko	**Risikobereich**		**Belastungs-höhe*)**	**a) Wahrscheinlichkeit körperlicher Überbeanspruchung** **b) Mögliche gesundheitliche Folgen**	**Maßnahmen**
	1	<20 Punkte	gering	a) Körperliche Überbeanspruchung ist unwahrscheinlich b) Gesundheitsgefährdung nicht zu erwarten	Keine
	2	20 – <50 Punkte	mäßig erhöht	a) Körperliche Überbeanspruchung ist bei vermindert belastbaren Personen möglich. b) Ermüdung, geringgradige Anpassungsbeschwerden, die in der Freizeit kompensiert werden können	Für vermindert belastbare Personen sind Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sinnvoll.
● ●	3	50 – <100 Punkte	wesentlich erhöht	a) Körperliche Überbeanspruchung ist auch für normal belastbare Personen möglich b) Beschwerden (Schmerzen) ggf. mit Funktionsstörungen, meistens reversibel, ohne morphologische Manifestation	Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sind zu prüfen.
	4	≥100 Punkte	hoch	a) Körperliche Überbeanspruchung ist wahrscheinlich. b) Stärker ausgeprägte Beschwerden und / oder Funktionsstörungen, Strukturschäden mit Krankheitswert	Maßnahmen zur Gestaltung sind erforderlich. Sonstige Präventionsmaßnahmen sind zu prüfen.

*) *Die Grenzen zwischen den Risikobereichen sind aufgrund der individuellen Arbeitstechniken und Leistungsvoraussetzungen fließend. Damit darf die Einstufung nur als Orientierungshilfe verstanden werden. Grundsätzlich ist davon auszugehen, dass mit steigenden Punktwerten die Wahrscheinlichkeit einer körperlichen Überbeanspruchung zunimmt.*

Entwurf zur Praxiserprobung – Version 12.5 – Stand 08.2020 – © BAuA/ASER/ArbMedErgo/ebus

Figure A.26 Second page of the conducted KIM risk assessment method regarding the collection of small waste materials activity.

Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen beim manuellen Heben, Halten und Tragen von Lasten ≥3 kg (LMM-HHT-E)

Arbeitsplatz / Teil-Tätigkeit:	Waste collection / Pick-up		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	33	Datum:	

Beschreibung der Teil-Tätigkeit

For the calculation of the time weighting factor:
Since in average there are two slit-containers at each collection site and the time measured corresponds to the total amount of time spent emptying all slit-containers, one must consider that in the calculation of the time weighting factor, namely in the determination of the "Häufigkeit".

"Häufigkeit":

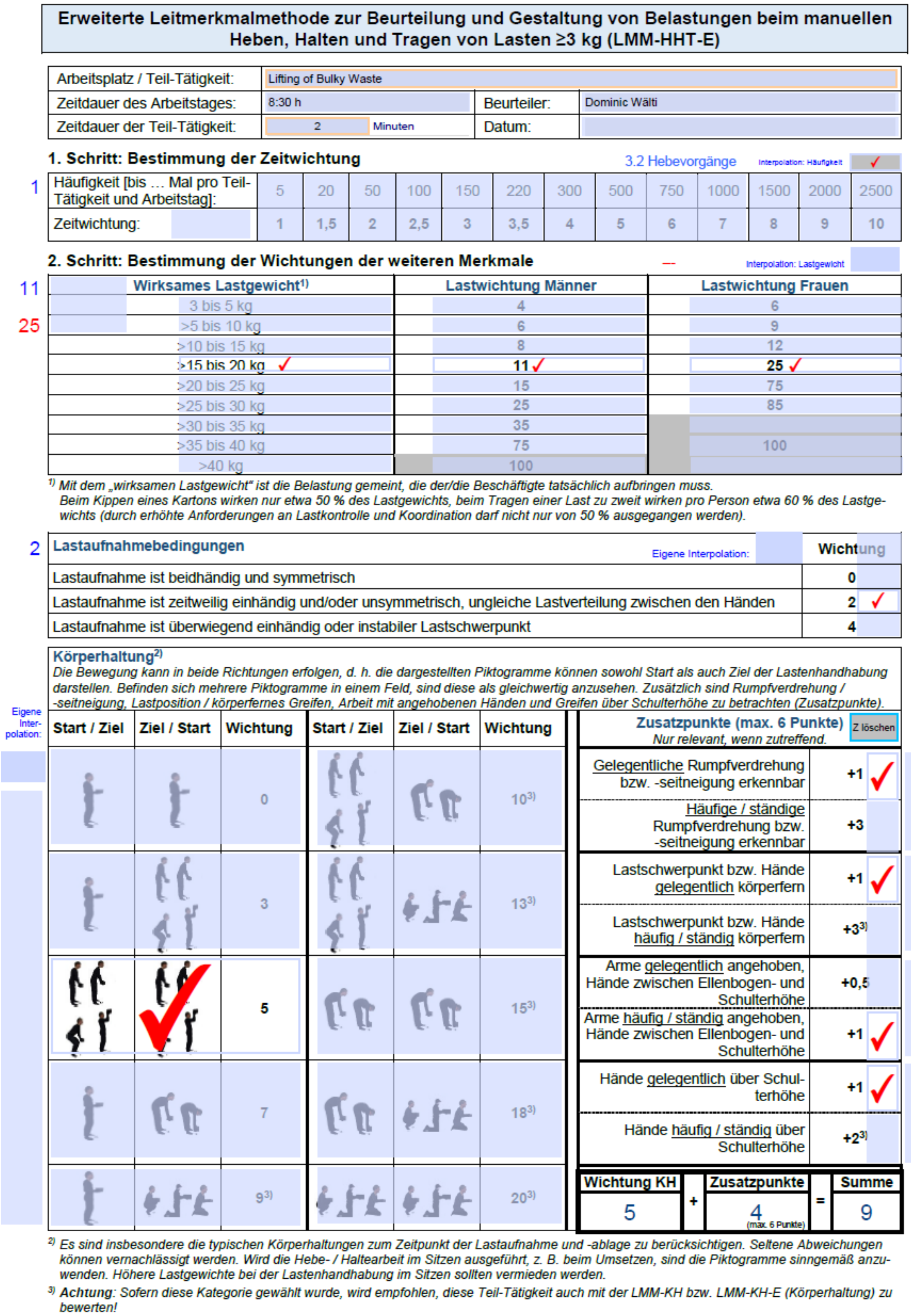
Since in average the worker spends 6 seconds to lift some waste from the floor:

Häufigkeit = Overall average time spent per day collecting small waste / Average time spent to lift some waste from the floor

= 1974 s / 6 s

= 329

Figure A.27 Third page of the conducted KIM risk assessment method regarding the collection of small waste materials activity.



Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen beim manuellen Heben, Halten und Tragen von Lasten ≥3 kg (LMM-HHT-E)

Arbeitsplatz / Teil-Tätigkeit:	Lifting of Bulky Waste		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	2 Minuten	Datum:	

1. Schritt: Bestimmung der Zeitwichtung — 3.2 Hebevorgänge — Interpolation: Häufigkeit ✓

1														
Häufigkeit [bis … Mal pro Teil-Tätigkeit und Arbeitstag]:	5	20	50	100	150	220	300	500	750	1000	1500	2000	2500
Zeitwichtung:	1	1,5	2	2,5	3	3,5	4	5	6	7	8	9	10

2. Schritt: Bestimmung der Wichtungen der weiteren Merkmale — Interpolation: Lastgewicht

	Wirksames Lastgewicht[1]	Lastwichtung Männer	Lastwichtung Frauen
11	3 bis 5 kg	4	6
25	>5 bis 10 kg	6	9
	>10 bis 15 kg	8	12
	>15 bis 20 kg ✓	11 ✓	25 ✓
	>20 bis 25 kg	15	75
	>25 bis 30 kg	25	85
	>30 bis 35 kg	35	
	>35 bis 40 kg	75	100
	>40 kg	100	

[1] *Mit dem „wirksamen Lastgewicht" ist die Belastung gemeint, die der/die Beschäftigte tatsächlich aufbringen muss. Beim Kippen eines Kartons wirken nur etwa 50 % des Lastgewichts, beim Tragen einer Last zu zweit wirken pro Person etwa 60 % des Lastgewichts (durch erhöhte Anforderungen an Lastkontrolle und Koordination darf nicht nur von 50 % ausgegangen werden).*

2 Lastaufnahmebedingungen (Eigene Interpolation:)	Wichtung
Lastaufnahme ist beidhändig und symmetrisch	0
Lastaufnahme ist zeitweilig einhändig und/oder unsymmetrisch, ungleiche Lastverteilung zwischen den Händen	2 ✓
Lastaufnahme ist überwiegend einhändig oder instabiler Lastschwerpunkt	4

Körperhaltung[2]

Die Bewegung kann in beide Richtungen erfolgen, d. h. die dargestellten Piktogramme können sowohl Start als auch Ziel der Lastenhandhabung darstellen. Befinden sich mehrere Piktogramme in einem Feld, sind diese als gleichwertig anzusehen. Zusätzlich sind Rumpfverdrehung / -seitneigung, Lastposition / körperfernes Greifen, Arbeit mit angehobenen Händen und Greifen über Schulterhöhe zu betrachten (Zusatzpunkte).

Eigene Inter-polation:

Start / Ziel	Ziel / Start	Wichtung	Start / Ziel	Ziel / Start	Wichtung
		0			10[3]
		3			13[3]
	✓	5			15[3]
		7			18[3]
		9[3]			20[3]

Zusatzpunkte (max. 6 Punkte) — Nur relevant, wenn zutreffend. (Z löschen)		
Gelegentliche Rumpfverdrehung bzw. -seitneigung erkennbar	+1	✓
Häufige / ständige Rumpfverdrehung bzw. -seitneigung erkennbar	+3	
Lastschwerpunkt bzw. Hände gelegentlich körperfern	+1	✓
Lastschwerpunkt bzw. Hände häufig / ständig körperfern	+3[3]	
Arme gelegentlich angehoben, Hände zwischen Ellenbogen- und Schulterhöhe	+0,5	
Arme häufig / ständig angehoben, Hände zwischen Ellenbogen- und Schulterhöhe	+1	✓
Hände gelegentlich über Schulterhöhe	+1	✓
Hände häufig / ständig über Schulterhöhe	+2[3]	

Wichtung KH	+	Zusatzpunkte	=	Summe
5	+	4 (max. 6 Punkte)	=	9

[2] *Es sind insbesondere die typischen Körperhaltungen zum Zeitpunkt der Lastaufnahme und -ablage zu berücksichtigen. Seltene Abweichungen können vernachlässigt werden. Wird die Hebe- / Haltearbeit im Sitzen ausgeführt, z. B. beim Umsetzen, sind die Piktogramme sinngemäß anzuwenden. Höhere Lastgewichte bei der Lastenhandhabung im Sitzen sollten vermieden werden.*

[3] ***Achtung**: Sofern diese Kategorie gewählt wurde, wird empfohlen, diese Teil-Tätigkeit auch mit der LMM-KH bzw. LMM-KH-E (Körperhaltung) zu bewerten!*

Figure A.28 First page of the conducted KIM risk assessment method regarding the lifting and loading of bulky goods activity.

Ungünstige Ausführungsbedingungen (nur angeben, wenn zutreffend) *In den Tabellen nicht genannte Merkmale sind sinngemäß zu berücksichtigen.* *Seltene Abweichungen sind vernachlässigbar.*		Zwi-schen-wichtung ZW		∑ ZW
Hand-/Armstellung-bewegung:	Gelegentlich am Ende der Beweglichkeitsbereiche	1	✓	5
	Häufig / ständig am Ende der Beweglichkeitsbereiche	2		
Kraftübertragung/-einleitung eingeschränkt: Lasten schlecht greifbar / erhöhte Haltekräfte erforderlich / keine gestalteten Griffe / Arbeitshandschuhe		1	✓	
Kraftübertragung/-einleitung erheblich behindert: Lasten kaum greifbar / schmierig, weich, scharfkantig / keine oder ungeeignete Griffe / Arbeitshandschuhe		2		
Umgebungsbedingungen eingeschränkt: Ungünstige Witterungsbedingungen und/oder Belastungen durch Hitze, Zugluft, Kälte, Nässe		1	✓	
Räumliche Bedingungen eingeschränkt: Zu kleine Arbeitsfläche unter 1,5 m², Boden ist mäßig verschmutzt, etwas uneben, leichte Neigung bis 5°, leicht eingeschränkte Standsicherheit, Last ist genau zu positionieren		1		
Räumliche Bedingungen ungünstig: Stark eingeschränkte Bewegungsfreiheit oder Bewegungsraum hat zu geringe Höhe, Arbeiten auf engem Raum, Boden ist stark verschmutzt, uneben oder grob gepflastert, Stufen / Schlaglöcher, stärkere Neigung 5–10°, eingeschränkte Standsicherheit, Last ist sehr genau zu positionieren		2[4)]		
Kleidung: Zusätzliche Belastung durch beeinträchtigende Kleidung oder Ausrüstung (z. B. Tragen schwerer Regenjacken, Ganzkörperschutzanzügen, Atemschutzgeräten, Werkzeuggürteln o. ä.)		1		
Erschwernis durch Halten / Tragen: Die Last ist zwischen >5 und 10 Sekunden zu halten oder über eine Strecke zwischen >2 m und 5 m zu tragen.		2	✓	
Deutliche Erschwernis durch Halten / Tragen: Die Last >10 Sekunden zu halten oder über eine Strecke >5 m zu tragen.		5[4)]		
Keine: Es liegen keine ungünstigen Ausführungsbedingen vor.		0		

4) Achtung: Sofern beim Tragen von Lasten ungünstige räumliche Bedingungen vorliegen oder die Last über Strecken >10 m zu tragen ist, ist diese Teil-Tätigkeit mit der LMM-KB bzw. LMM-KB-E zu bewerten!

Arbeitsorganisation / Zeitliche Verteilung Eigene Interpolation:	Wichtung		2
Gut: Häufig Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / ohne enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	0		
Eingeschränkt: Selten Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / gelegentlich enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	2	✓	
Ungünstig: Kein/kaum Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / häufig enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag mit zeitweise hohen Belastungsspitzen.	4		

3. Schritt: Bewertung und Beurteilung

	M	W
Wirksames Lastgewicht	11	25
Lastaufnahmebedingungen +	2	
Summe Körperhaltung +	9	
Ungünstige Ausführungsbedingungen (∑ ZW) +	5	
Arbeitsorganisation / Zeitliche Verteilung +	2	

Zeitwichtung		Summe Merkmalswichtungen: M	W	=	Ergebnisse M	W
1	x	29	43	=	29	43

Anhand des errechneten Punktwertes und der folgenden Tabelle kann eine grobe Beurteilung vorgenommen werden:

Risiko	Risikobereich		Belastungs-höhe*)	a) Wahrscheinlichkeit körperlicher Überbeanspruchung b) Mögliche gesundheitliche Folgen	Maßnahmen
	1	<20 Punkte	gering	a) Körperliche Überbeanspruchung ist unwahrscheinlich b) Gesundheitsgefährdung nicht zu erwarten	Keine
M ●, W ●	2	20 – <50 Punkte	mäßig erhöht	a) Körperliche Überbeanspruchung ist bei vermindert belastbaren Personen möglich. b) Ermüdung, geringgradige Anpassungsbeschwerden, die in der Freizeit kompensiert werden können	Für vermindert belastbare Personen sind Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sinnvoll.
	3	50 – <100 Punkte	wesentlich erhöht	a) Körperliche Überbeanspruchung ist auch für normal belastbare Personen möglich b) Beschwerden (Schmerzen) ggf. mit Funktionsstörungen, meistens reversibel, ohne morphologische Manifestation	Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sind zu prüfen.
	4	≥100 Punkte	hoch	a) Körperliche Überbeanspruchung ist wahrscheinlich. b) Stärker ausgeprägte Beschwerden und / oder Funktionsstörungen, Strukturschäden mit Krankheitswert	Maßnahmen zur Gestaltung sind erforderlich. Sonstige Präventionsmaßnahmen sind zu prüfen.

**) Die Grenzen zwischen den Risikobereichen sind aufgrund der individuellen Arbeitstechniken und Leistungsvoraussetzungen fließend. Damit darf die Einstufung nur als Orientierungshilfe verstanden werden. Grundsätzlich ist davon auszugehen, dass mit steigenden Punktwerten die Wahrscheinlichkeit einer körperlichen Überbeanspruchung zunimmt.*

Figure A.29 Second page of the conducted KIM risk assessment method regarding the lifting and loading of bulky goods activity.

Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen beim manuellen Heben, Halten und Tragen von Lasten ≥3 kg (LMM-HHT-E)

Arbeitsplatz / Teil-Tätigkeit:	Lifting of Bulky Waste		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	2	Datum:	

Beschreibung der Teil-Tätigkeit

For the calculation of the time weighting factor:

Average total amount of time per day required for the lifting task of bulky waste = 76.2s = 1.27min
Average number of executions per day: 3.2
(Both from Excel Sheet)

Figure A.30 Third page of the conducted KIM risk assessment method regarding the lifting and loading of bulky goods activity.

Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen bei der Ausübung von Ganzkörperkräften (LMM-GK-E)

Arbeitsplatz / Teil-Tätigkeit:	Throwing the Waste Bag into the Truck		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	6 Minuten	Datum:	

1. Schritt: Bestimmung der Zeitwichtung 6 Minuten bzw. Aktionen — Interpolation: Dauer oder Häufigkeit ✓

Gesamtdauer[1] [bis … Minuten] bzw. Wiederholungshäufigkeit[2] der Teil-Tätigkeit pro Arbeitstag:	≤1	>1 – 5	>5 – 10	>10 – 20	>20 – 30	>30 – 45	>45 – 60	>60 – 100	>100 – 150	>50 – 210	>210 – 270	>270 – 360	>360 – 480
1.6 Zeitwichtung	1	1,5	2	2,5	3	3,5	4	5	6	7	8	9	10

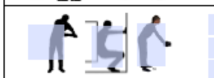
[1] Bei kontinuierlichen Teil-Tätigkeiten, [2] bei diskontinuierlichen Teil-Tätigkeiten. Erläuterungen hierzu: Siehe Handlungsanleitung.
Achtung: Sofern überwiegend Finger-Hand-Kräfte ausgeführt werden ist die Teil-Tätigkeit auch mit der LMM-MA bzw. LMM-MA-E zu bewerten!

2. Schritt: Bestimmung der Wichtungen der weiteren Merkmale Interpolationsfelder ein/aus (Haltedauer und Häufigkeit direkt angeben)

Kraftausübung(en) in einer Norm-Minute bei kontinuierlichen Teil-Tätigkeiten bzw. pro Teil-Tätigkeit bei diskontinuierlichen Teil-Tätigkeiten		Halten[3] mittl. Haltedauer [Sekunden]			Bewegen mittl. Bewegungshäufigkeiten [Anzahl]			
Höhe	typische Beispiele als orientierende Einstufungshilfen	31 – 45[3]	16 – 30	≤15	<5	5 – 15	16 – 30	31 – 45[5]
gering	**Geringe Kräfte** Ganzkörperkräfte mit geringen Kräften können definitionsgemäß nicht vorkommen. Diese Teil-Tätigkeiten sind ggfs. mit der LMM-MA bzw. LMM-MA-E zu beurteilen.	-	-	-	-	-	-	-
	Mittlere Kräfte (bis 30 % F_{max}M) Arbeiten mit handgeführten Werkzeugen wie Winkelschleifer, kleine Kettensägen, Heckenscheren oder Schlagbohrmaschinen <3 kg / Bewegen von Lasten auf Rollenbahnen <20 kg	18	12	6	1,5	6	12	18
	Hohe Kräfte (bis 50 % F_{max}M) Arbeiten mit schwereren handgeführten Werkzeugen wie Trennschleifer, größere Kettensägen, Bohrhammer 3–8 kg / Bedienen von Hochdruckreiniger oder Sandstrahler / Schaufeln von Lasten <4 kg / Bewegen von Lasten auf Rollenbahnen 20–50 kg / Werfen von Lasten <3 kg bis max. 5 Meter	25	17	8	2	8	17	25
	Sehr hohe Kräfte (bis 80 % F_{max}M) Arbeiten mit schweren handgeführten Werkzeugen wie Drucklufthämmern (≥8 kg) / Schaufeln von Lasten 4–8 kg / Bewegen von Lasten auf Rollenbahnen >50–100 kg / Werfen von Lasten <3 kg bis max. 10 Meter oder 3–5 kg max. 5 Meter	100	32	15	4	15 ✓	32	100
hoch	**Spitzenkräfte**[4] (über 80 % F_{max}M) Impulsartige Kraftaufwendungen wie beim Arbeiten mit Brechstange, Vorschlaghammer / Ankippen schwerer Fässer (>200 kg), Transport schwerer Möbel / Schaufeln von Lasten >8 kg / Bewegen von Lasten auf Rollenbahnen >100 kg / Werfen von Lasten <3 kg über 10 Meter oder ≥3 kg über 5 Meter	100		25	6	25	50	100
Die Teil-Tätigkeit ist zu beobachten und die Wichtungen für die Kraftkategorien zu markieren. Addiert ergeben diese die Gesamtkraftwichtung.		**Gesamtkraftwichtung:**					15	
		Bei Frauen x 1,5:					22.5	

[3] Als Haltearbeit werden nur dann Zeitanteile berücksichtigt, wenn ein Arm mindestens 4 Sekunden durchgehend statisch gehalten wird!
[4] Ggfs. können diese Kräfte gar nicht oder nicht mehr sicher aufgebracht werden. Dies gilt insbesondere für Frauen.
[5] Bei noch höheren Häufigkeiten/Haltedauern ist die Merkmalswichtung zu extrapolieren (mit hinterlegtem Algorithmus).

4 **Symmetrie der Kraftaufwendung** Eigene Interpolation:	**Wichtung**
Kraftaufwendung ist beidhändig und symmetrisch	0
Kraftaufwendung ist zeitweilig einhändig und/oder unsymmetrisch: ungleiche Kraftverteilung zwischen den Händen	2
Kraftaufwendung ist überwiegend einhändig, ungleiche Verteilung oder Richtung der Kräfte beider Hände	4 ✓

6 **Körperhaltung**[6]	Eigene Interpolation:	**Wichtung**
	- Aufrechtes bis leicht vorgeneigtes Stehen (<20° Vorneigung) - Keine Verdrehung	0
	- Stehen, stärker (20–60°) vorgeneigt - Gelegentliche Rumpfverdrehung bzw. -seitneigung erkennbar - Hände gelegentlich über Schulterniveau / körperfern	3
	- Stehen, stark vorgeneigt (>60°) oder rückgeneigt - Häufige Rumpfverdrehung bzw. -seitneigung erkennbar - Hände häufig über Schulterniveau / körperfern - Arbeiten im Liegen mit Händen oberhalb/unterhalb des Körpers	6 ✓
	- Kombination aus stärkerer Vor- oder Rückneigung mit Seitneigung/Torsion - Ständige Rumpfverdrehung bzw. -seitneigung erkennbar - Arbeiten im Hocken oder Knien - Hände ständig über Schulterniveau / körperfern	9[7]

[6] Es sind die typischen Körperhaltungen zu berücksichtigen. Seltene Abweichungen können vernachlässigt werden.
[7] Achtung: Sofern diese Kategorie gewählt wurde, wird empfohlen, diese Teil-Tätigkeit auch mit der LMM-KH bzw. LMM-KH-E zu bewerten!

Figure A.31 First page of the conducted KIM risk assessment method regarding the throwing waste bags into the transport vehicle activity.

Ungünstige Ausführungsbedingungen (nur angeben, wenn zutreffend) Hinweis: Hier können für ungünstige Ausführungsbedingungen Zusatzpunkte (Zwischenwichtungen) vergeben werden		**Zwischen-wichtung (ZW)**		**∑ ZW**
Hand-/Armstellung-bewegung:	Gelegentlich am Ende der Beweglichkeitsbereiche	1	✓	3
	Häufig/ ständig am Ende der Beweglichkeitsbereiche	2		
Kraftübertragung/-einleitung eingeschränkt Gegenstände/Werkzeuge schlecht greifbar / erhöhte Haltekräfte erforderlich / keine gestalteten Griffe		1	✓	
Kraftübertragung/-einleitung erheblich behindert Gegenstände/Werkzeuge kaum greifbar / schmierig, weich, scharfkantig / keine oder ungeeignete Griffe		2		
Umgebungsbedingungen eingeschränkt: Belastungen durch Hitze, Kälte und/oder Vibration[8)]		1	✓	
Umgebungsbedingungen ungünstig: Belastungen durch extreme Hitze, Kälte und/oder Vibration[8)]		2		
Erhöhte Anstrengung durch eingeschränkte räumliche Bedingungen Eingeschränkte Standsicherheit und/oder eingeschränkter Bewegungsraum, z. B. zu geringe Höhe oder Arbeitsfläche unter 1,5 m² / Boden etwas rutschig, leichte Neigung (bis 5°), Hindernisse im Arbeitsbereich		1		
Stark erhöhte Anstrengung durch ungünstige räumliche Bedingungen Stark eingeschränkte Standsicherheit und/oder Bewegungsfreiheit, z. B. bei Arbeiten auf sehr engem Raum / Boden ist sehr rutschig/uneben, stärkere Neigung (>5°)		2		
Kleidung: Zusätzliche Belastung durch beeinträchtigende und schwere Schutzkleidung/-ausrüstung (PSA) (z. B. Hitzeschutzanzüge, Chemikalienschutzanzüge, schwere Atemschutzausrüstung (Gruppe 3))		2		
Keine: Es liegen keine ungünstigen Ausführungsbedingungen vor.		0		

In den Tabellen nicht genannte Merkmale sind sinngemäß zu berücksichtigen. Seltene Abweichungen sind vernachlässigbar.
8) Achtung: Sofern Vibrationsbelastungen vorkommen, sind diese gesondert zu bewerten! Siehe http://www.baua.de/vibration/

Arbeitsorganisation / Zeitliche Verteilung Eigene Interpolation:	**Wichtung** 2
Gut: Häufig Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / ohne enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	0
Eingeschränkt: Selten Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / gelegentlich enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	2 ✓
Ungünstig: Kein/kaum Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / häufig enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag mit zeitweise hohen Belastungsspitzen.	4

3. Schritt: Bewertung und Beurteilung

		M	W
Kraftausübung(en)		15	22.5
Symmetrie der Kraftaufwendung	+	4	
Körperhaltung	+	6	
Ungünstige Ausführungsbedingungen (∑ ZW)	+	3	
Arbeitsorganisation / Zeitliche Verteilung	+	2	

1.6 **Zeitwichtung**	x	**Summe Merkmalswichtungen:**	M: 30	W: 37.5	=	**Ergebnisse** M: 48	W: 60

Anhand des errechneten Punktwertes und der folgenden Tabelle kann eine grobe Beurteilung vorgenommen werden:

Risiko	Risikobereich	Belastungs-höhe[*)]	a) Wahrscheinlichkeit körperlicher Überbeanspruchung b) Mögliche gesundheitliche Folgen	Maßnahmen
1	<20 Punkte	gering	a) Körperliche Überbeanspruchung ist unwahrscheinlich b) Gesundheitsgefährdung nicht zu erwarten	Keine
2	20 – <50 Punkte	mäßig erhöht	a) Körperliche Überbeanspruchung ist bei vermindert belastbaren Personen möglich. b) Ermüdung, geringgradige Anpassungsbeschwerden, die in der Freizeit kompensiert werden können	Für vermindert belastbare Personen sind Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sinnvoll.
3	50 – <100 Punkte	wesentlich erhöht	a) Körperliche Überbeanspruchung ist auch für normal belastbare Personen möglich b) Beschwerden (Schmerzen) ggf. mit Funktionsstörungen, meistens reversibel, ohne morphologische Manifestation	Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sind zu prüfen.
4	≥100 Punkte	hoch	a) Körperliche Überbeanspruchung ist wahrscheinlich. b) Stärker ausgeprägte Beschwerden und / oder Funktionsstörungen, Strukturschäden mit Krankheitswert	Maßnahmen zur Gestaltung sind erforderlich. Sonstige Präventionsmaßnahmen sind zu prüfen.

**) Die Grenzen zwischen den Risikobereichen sind aufgrund der individuellen Arbeitstechniken und Leistungsvoraussetzungen fließend. Damit darf die Einstufung nur als Orientierungshilfe verstanden werden. Grundsätzlich ist davon auszugehen, dass mit steigenden Punktwerten die Wahrscheinlichkeit einer körperlichen Überbeanspruchung zunimmt.*

Figure A.32 Second page of the conducted KIM risk assessment method regarding the throwing waste bags into the transport vehicle activity.

Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen bei der Ausübung von Ganzkörperkräften (LMM-GK-E)

Arbeitsplatz / Teil-Tätigkeit:	Throwing the Waste Bag into the Truck		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	6	Datum:	

Beschreibung der Teil-Tätigkeit

For the calculation of the time weighting factor:

Average amount of waste collection sites per day = 38 (from Excel Sheet)
Average amount of slit containers per collection site = 2
--> 76 waste bags in average per day = 76 throwing actions

Estimation of time required to throw the waste bag into the truck = 5s

--> Total amount of time: 76 * 5s = 380s = 6.3333 min

Figure A.33 Third page of the conducted KIM risk assessment method regarding the throwing waste bags into the transport vehicle activity.

Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen bei der Ausübung von Ganzkörperkräften (LMM-GK-E)

Arbeitsplatz / Teil-Tätigkeit:	Pushing / Pulling of Bulky Waste		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	1 Minuten	Datum:	

1. Schritt: Bestimmung der Zeitwichtung 1 Minute bzw. Aktion — Interpolation: Dauer oder Häufigkeit

Gesamtdauer[1] [bis … Minuten] bzw. Wiederholungshäufigkeit[2] der Teil-Tätigkeit pro Arbeitstag:	≤1 ✓	>1 – 5	>5 – 10	>10 – 20	>20 – 30	>30 – 45	>45 – 60	>60 – 100	>100 – 150	>50 – 210	>210 – 270	>270 – 360	>360 – 480
1 Zeitwichtung	1	1,5	2	2,5	3	3,5	4	5	6	7	8	9	10

[1] Bei kontinuierlichen Teil-Tätigkeiten, [2] bei diskontinuierlichen Teil-Tätigkeiten. Erläuterungen hierzu: Siehe Handlungsanleitung.
Achtung: Sofern überwiegend Finger-Hand-Kräfte ausgeführt werden ist die Teil-Tätigkeit auch mit der LMM-MA bzw. LMM-MA-E zu bewerten!

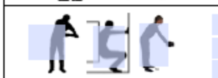
2. Schritt: Bestimmung der Wichtungen der weiteren Merkmale — Interpolationsfelder ein/aus (Haltedauer und Häufigkeit direkt angeben)

Kraftausübung(en) in einer Norm-Minute bei kontinuierlichen Teil-Tätigkeiten bzw. pro Teil-Tätigkeit bei diskontinuierlichen Teil-Tätigkeiten		Halten[3] mittl. Haltedauer [Sekunden]			Bewegen mittl. Bewegungshäufigkeiten [Anzahl]			
Höhe	**typische Beispiele als orientierende Einstufungshilfen**	31 – 45[3]	16 – 30	≤15	<5	5 – 15	16 – 30	31 – 45[5]
gering	**Geringe Kräfte** Ganzkörperkräfte mit geringen Kräften können definitionsgemäß nicht vorkommen. Diese Teil-Tätigkeiten sind ggfs. mit der LMM-MA bzw. LMM-MA-E zu beurteilen.	-	-	-	-	-	-	-
	Mittlere Kräfte (bis 30 % F_{max}M) Arbeiten mit handgeführten Werkzeugen wie Winkelschleifer, kleine Kettensägen, Heckenscheren oder Schlagbohrmaschinen <3 kg / Bewegen von Lasten auf Rollenbahnen <20 kg	18	12	6	1,5	6	12	18
	Hohe Kräfte (bis 50 % F_{max}M) Arbeiten mit schwereren handgeführten Werkzeugen wie Trennschleifer, größere Kettensägen, Bohrhammer 3–8 kg / Bedienen von Hochdruckreiniger oder Sandstrahler / Schaufeln von Lasten <4 kg / Bewegen von Lasten auf Rollenbahnen 20–50 kg / Werfen von Lasten <3 kg bis max. 5 Meter	25	17	8	2	8	17	25
	Sehr hohe Kräfte (bis 80 % F_{max}M) Arbeiten mit schweren handgeführten Werkzeugen wie Drucklufthämmern (≥8 kg) / Schaufeln von Lasten 4–8 kg / Bewegen von Lasten auf Rollenbahnen >50–100 kg / Werfen von Lasten <3 kg bis max. 10 Meter oder 3–5 kg max. 5 Meter	100	32	15 ✓	4 ✓	15	32	100
hoch	**Spitzenkräfte**[4] (über 80 % F_{max}M) Impulsartige Kraftaufwendungen wie beim Arbeiten mit Brechstange, Vorschlaghammer / Ankippen schwerer Fässer (>200 kg), Transport schwerer Möbel / Schaufeln von Lasten >8 kg / Bewegen von Lasten auf Rollenbahnen >100 kg / Werfen von Lasten <3 kg über 10 Meter oder ≥3 kg über 5 Meter	100		25	6	25	50	100

Die Teil-Tätigkeit ist zu beobachten und die Wichtungen für die Kraftkategorien zu markieren. Addiert ergeben diese die Gesamtkraftwichtung.	**Gesamtkraftwichtung:**	19
	Bei Frauen x 1,5:	28.5

[3] Als Haltearbeit werden nur dann Zeitanteile berücksichtigt, wenn ein Arm mindestens 4 Sekunden durchgehend statisch gehalten wird!
[4] Ggfs. können diese Kräfte gar nicht oder nicht mehr sicher aufgebracht werden. Dies gilt insbesondere für Frauen.
[5] Bei noch höheren Häufigkeiten/Haltedauern ist die Merkmalswichtung zu extrapolieren (mit hinterlegtem Algorithmus).

2 **Symmetrie der Kraftaufwendung** (Eigene Interpolation:)	**Wichtung**
Kraftaufwendung ist beidhändig und symmetrisch	0
Kraftaufwendung ist zeitweilig einhändig und/oder unsymmetrisch: ungleiche Kraftverteilung zwischen den Händen	2 ✓
Kraftaufwendung ist überwiegend einhändig, ungleiche Verteilung oder Richtung der Kräfte beider Hände	4

3 **Körperhaltung**[6]	(Eigene Interpolation:)	**Wichtung**
	- Aufrechtes bis leicht vorgeneigtes Stehen (<20° Vorneigung) - Keine Verdrehung	0
	- Stehen, stärker (20–60°) vorgeneigt - Gelegentliche Rumpfverdrehung bzw. -seitneigung erkennbar - Hände gelegentlich über Schulterniveau / körperfern	3 ✓
	- Stehen, stark vorgeneigt (>60°) oder rückgeneigt - Häufige Rumpfverdrehung bzw. -seitneigung erkennbar - Hände häufig über Schulterniveau / körperfern - Arbeiten im Liegen mit Händen oberhalb/unterhalb des Körpers	6
	- Kombination aus stärkerer Vor- oder Rückneigung mit Seitneigung/Torsion - Ständige Rumpfverdrehung bzw. -seitneigung erkennbar - Arbeiten im Hocken oder Knien - Hände ständig über Schulterniveau / körperfern	9[7]

[6] Es sind die typischen Körperhaltungen zu berücksichtigen. Seltene Abweichungen können vernachlässigt werden.
[7] Achtung: Sofern diese Kategorie gewählt wurde, wird empfohlen, diese Teil-Tätigkeit auch mit der LMM-KH bzw. LMM-KH-E zu bewerten!

Figure A.34 First page of the conducted KIM risk assessment method regarding the pushing and pulling of bulky goods activity.

Ungünstige Ausführungsbedingungen (nur angeben, wenn zutreffend) Hinweis: Hier können für ungünstige Ausführungsbedingungen Zusatzpunkte (Zwischenwichtungen) vergeben werden			Zwischen-wichtung (ZW)	∑ ZW
Hand-/Armstellung-bewegung: 	Gelegentlich am Ende der Beweglichkeitsbereiche	◆	1	3
	Häufig/ ständig am Ende der Beweglichkeitsbereiche		2	
Kraftübertragung/-einleitung eingeschränkt Gegenstände/Werkzeuge schlecht greifbar / erhöhte Haltekräfte erforderlich / keine gestalteten Griffe			1	
Kraftübertragung/-einleitung erheblich behindert Gegenstände/Werkzeuge kaum greifbar / schmierig, weich, scharfkantig / keine oder ungeeignete Griffe			2 ✓	
Umgebungsbedingungen eingeschränkt: Belastungen durch Hitze, Kälte und/oder Vibration[8]			1 ✓	
Umgebungsbedingungen ungünstig: Belastungen durch extreme Hitze, Kälte und/oder Vibration[8]			2	
Erhöhte Anstrengung durch eingeschränkte räumliche Bedingungen Eingeschränkte Standsicherheit und/oder eingeschränkter Bewegungsraum, z. B. zu geringe Höhe oder Arbeitsfläche unter 1,5 m² / Boden etwas rutschig, leichte Neigung (bis 5°), Hindernisse im Arbeitsbereich		◆	1	
Stark erhöhte Anstrengung durch ungünstige räumliche Bedingungen Stark eingeschränkte Standsicherheit und/oder Bewegungsfreiheit, z. B. bei Arbeiten auf sehr engem Raum / Boden ist sehr rutschig/uneben, stärkere Neigung (>5°)			2	
Kleidung: Zusätzliche Belastung durch beeinträchtigende und schwere Schutzkleidung/-ausrüstung (PSA) (z. B. Hitzeschutzanzüge, Chemikalienschutzanzüge, schwere Atemschutzausrüstung (Gruppe 3))		◆	2	
Keine: Es liegen keine ungünstigen Ausführungsbedingungen vor.		◆	0	

In den Tabellen nicht genannte Merkmale sind sinngemäß zu berücksichtigen. Seltene Abweichungen sind vernachlässigbar.
[8] Achtung: Sofern Vibrationsbelastungen vorkommen, sind diese gesondert zu bewerten! Siehe http://www.baua.de/vibration/

Arbeitsorganisation / Zeitliche Verteilung — Eigene Interpolation: ✓	Wichtung 1
Gut: Häufig Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / ohne enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	0
Eingeschränkt: Selten Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / gelegentlich enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	2
Ungünstig: Kein/kaum Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / häufig enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag mit zeitweise hohen Belastungsspitzen.	4

3. Schritt: Bewertung und Beurteilung

		M	W
Kraftausübung(en)		19	28.5
Symmetrie der Kraftaufwendung	+	2	
Körperhaltung	+	3	
Ungünstige Ausführungsbedingungen (∑ ZW)	+	3	
Arbeitsorganisation / Zeitliche Verteilung	+	1	

Zeitwichtung	x	Summe Merkmalswichtungen: M	Summe Merkmalswichtungen: W	=	Ergebnisse M	Ergebnisse W
1	x	28	37.5	=	28	37.5

Anhand des errechneten Punktwertes und der folgenden Tabelle kann eine grobe Beurteilung vorgenommen werden:

Risiko	Risikobereich		Belastungs-höhe*)	a) Wahrscheinlichkeit körperlicher Überbeanspruchung b) Mögliche gesundheitliche Folgen	Maßnahmen
	1	<20 Punkte	gering	a) Körperliche Überbeanspruchung ist unwahrscheinlich b) Gesundheitsgefährdung nicht zu erwarten	Keine
● ● (M, W)	2	20 – <50 Punkte	mäßig erhöht	a) Körperliche Überbeanspruchung ist bei vermindert belastbaren Personen möglich. b) Ermüdung, geringgradige Anpassungsbeschwerden, die in der Freizeit kompensiert werden können	Für vermindert belastbare Personen sind Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sinnvoll.
	3	50 – <100 Punkte	wesentlich erhöht	a) Körperliche Überbeanspruchung ist auch für normal belastbare Personen möglich b) Beschwerden (Schmerzen) ggf. mit Funktionsstörungen, meistens reversibel, ohne morphologische Manifestation	Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sind zu prüfen.
	4	≥100 Punkte	hoch	a) Körperliche Überbeanspruchung ist wahrscheinlich. b) Stärker ausgeprägte Beschwerden und / oder Funktionsstörungen, Strukturschäden mit Krankheitswert	Maßnahmen zur Gestaltung sind erforderlich. Sonstige Präventionsmaßnahmen sind zu prüfen.

**) Die Grenzen zwischen den Risikobereichen sind aufgrund der individuellen Arbeitstechniken und Leistungsvoraussetzungen fließend. Damit darf die Einstufung nur als Orientierungshilfe verstanden werden. Grundsätzlich ist davon auszugehen, dass mit steigenden Punktwerten die Wahrscheinlichkeit einer körperlichen Überbeanspruchung zunimmt.*

Figure A.35 Second page of the conducted KIM risk assessment method regarding the pushing and pulling of bulky goods activity.

Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen bei der Ausübung von Ganzkörperkräften (LMM-GK-E)

Arbeitsplatz / Teil-Tätigkeit:	Pushing / Pulling of Bulky Waste		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	1	Datum:	

Beschreibung der Teil-Tätigkeit

For the calculation of the time weighting factor:

Total amount of time per day required for all pushing/pulling tasks of bulky waste = 0.6 min (from Excel Sheet)

Figure A.36 Third page of the conducted KIM risk assessment method regarding the pushing and pulling of bulky goods activity.

Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen bei Körperfortbewegung (LMM-KB-E)

Arbeitsplatz / Teil-Tätigkeit:	Carrying of the Waste Bag		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	10 Minuten	Datum:	

1. Schritt: Bestimmung der Zeitwichtung — 10 Minuten — Interpolation: Zeitdauer

2 Gesamtdauer der Teil-Tätigkeit [bis … Minuten] pro Arbeitstag:	≤1	> 1 – 5	>5 – 10	>10 – 20	>20 – 30	>30 – 45	>45 – 60	>60 – 100	>100 – 150	>150 – 210	>210 – 270	>70 – 360	>360 – 480
Zeitwichtung	1	1,5	2 ✓	2,5	3	3,5	4	5	6	7	8	9	10

2. Schritt: Bestimmung der Wichtungen der weiteren Merkmale

A Körperfortbewegung ohne Hilfsmittel

12

Art		Beschreibung (Interpolation: Lastgewicht [kg])	ohne/ <3 kg	3 … 10 kg	>0 … 15 kg	>15 … 20 kg	> 20 … 25 kg	>5 … 30 kg	>30 … 35 kg	>35 … 40 kg	> 40 kg
			Mitbewegte Lastmasse								
	Gehen	Langsam	4	6	8	10	12	14	25	35	
		Mittel (3 … 5 km/h)	8	10	12 ✓	14	16	18	30	40	
		Schnell	12	14	16	18	20	22	35	50	
	Steigen	Neigungswinkel <5°	10	12	14	16	18	20	35	50	
		Neigungswinkel 5 – 15°	12	14	16	18	20	22	35	50	
		Neigungswinkel >15°	24	26	28	30	32	34	40	50	
	Treppen steigen	Normale Treppe	18	20	22	24	26	50	100 [1]		
		Steile Treppen (35 … 50°	24	26	28	30	50	100 [1]			
		Sehr steile Treppen (>50°	30	32	34	50	100 [1]				100 [1]
	Besteigen von Leitern Anstellwinkel 65 ... 75°		24	26	50	100 [1]					
	Klettern Aufstiegswinkel >80° Vertikale Bewegung auf Steigeisen, Steigleitern, Steigeisengängen		30	32	50	100 [1]					
	Kriechen[2], stark gebücktes Gehen Überwiegend horizontale Bewegung in höhenverminderten Räumen, Stollen, Wartungsebenen, Kanälen		24	26	50	100 [1]					

1) Bei dieser Kombination aus Art der Fortbewegung und Lastentransport entsteht ein erhöhtes Risiko auch bei kurzen Expositionszeiten.
2) Bei dieser Fortbewegungsart ist die Teil-Tätigkeit auch mit der LMM-KH bzw. LMM-KH-E Teil C zu bewerten.

4 Lage des Lastschwerpunktes bei A (Interpolation d. Lastgewichts [kg]: ---)	Mitbewegte Lastmasse: 3 bis 15 kg	>15 … 30 kg	>30 kg
Keine Last oder Last <3 kg oder Last ist körpernah im Tragegestell oder Rucksack auf den Schultern	0		
Last körpernah, mit den Händen gehalten oder auf einer Schulter getragen	4 ✓	8	12
Last körperfern, mit den Händen gehalten [3]	8	12	16

2 Rumpfhaltung bei A (Interpolation d. Lastgewichts [kg]: ---)		Mitbewegte Lastmasse: 0 bis 15 kg	> 15 .. 30 kg	> 30 kg
Rumpf deutlich vorgeneigt und/oder Rumpfverdrehung bzw. -seitneigung erkennbar	Gelegentlich	2 ✓	4	6
	Häufig bis ständig [3]	4	6	8

3) Achtung: Sofern häufig bis ständig ungünstige Arm- oder Rumpfhaltungen vorkommen ist die Teil-Tätigkeit auch mit der LMM-HHT bzw. LMM-HHT-E (bei Last ≥3 kg) oder der LMM-KH bzw. LMM-KH-E (keine Last oder Last <3 kg) zu bewerten.

Ungünstige Ausführungsbedingungen bei A (Nur angeben, wenn zutreffend. In den Tabellen nicht genannte Merkmale sind sinngemäß zu berücksichtigen. Seltene Abweichungen sind vernachlässigbar.) Eigene Interpolation:	Wichtung	
Eingeschränkt: Eingeengter Bewegungsraum (z. B. Absturzsicherung durch Rückenschutz) / verminderte Standsicherheit durch beweglichen oder geneigten Trittbereich / **Sand- / Schotterweg**	3	
Stark eingeschränkt: Behinderung der Bewegungsmöglichkeit / keine technischen Aufstiegshilfen (natürliche Bedingungen) / **freies Gelände**	5	
0 **Kritisch:** Starke Behinderung der Bewegungsmöglichkeit durch Engstellen und Gefahrenstellen / eingeschränkte Sicht / keine Ruhebühnen / Bergsteigen / Atemschutzgeräte / **morastiger Untergrund**	15	
1 **Klima**: Extreme Klimaeinflüsse wie z. B. Hitze, Wind, Schnee (in den Abstufungen selten/gelegentlich und häufig/ständig) Eigene Interpolation: ✓	4	8
Summe aus eingeschränkt, stark eingeschränkt oder kritisch und Klima (falls zutreffend)	1	

Figure A.37 First page of the conducted KIM risk assessment method regarding the carrying of a waste bag activity.

B Körperfortbewegung beim Fahren mit Muskelkraft

Art	Beschreibung --- Interpolation d. Lastgewichts [kg]:	Zu bewegendes Lastgewicht inklusive Fahrzeug [4)] bis 50 kg	>50 ... 150 kg	>150 kg
	Langsam <10 km/h	3	6	9
	Mittel 10 ...15 km/h	6	10	14
	Schnell >15 km/h	9	15	21

Fahrweg - ungünstige Ausführungsbedingungen bei B --- (Nur angeben, wenn zutreffend. In den Tabellen nicht genannte Merkmale sind sinngemäß zu berücksichtigen. Seltene Abweichungen sind vernachlässigbar.)	Zu bewegendes Lastgewicht inklusive Fahrzeug [4)] bis 50 kg	>50 ... 150 kg	>150 kg	
Fahrweg eingeschränkt: unbefestigter oder grob gepflasterter Fahrweg, Schlaglöcher, starke Verschmutzung, zeitweilig Steigungen (Interpolation d. Lastgewichts [kg]:)	8	12	16	0
Klima: Extreme Klimaeinflüsse wie z. B. Hitze, Wind, Schnee (Eigene Interpolation:)	selten/gelegentlich 4		häufig/ständig 8	0
Summe	0			

[4)] *Bei unterstützendem Elektrobetrieb sind die Wichtungszahlen zu halbieren.*

Arbeitsorganisation / Zeitliche Verteilung (Bitte immer ausfüllen. Gilt entweder für A oder für B.) Eigene Interpolation:	Wichtung	
Gut: Häufig Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / ohne enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	0	2
Eingeschränkt: Selten Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / gelegentlich enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag.	2 ✓	
Ungünstig: Kein/kaum Belastungswechsel durch andere Tätigkeiten (mit anderen Belastungsarten) / häufig enge Abfolge von höheren Belastungen innerhalb einer Belastungsart an einem Arbeitstag mit zeitweise hohen Belastungsspitzen.	4	

3. Schritt: Bewertung und Beurteilung

A: Körperfortbewegung und mitbewegte Last		12
Lage des Lastschwerpunkts (nur bei A, sonst 0)	+	4
Rumpfverdrehung bzw. -seitneigung (nur bei A, sonst 0)	+	2
Ungünstige Ausführungsbedingungen (nur bei A, sonst 0)	+	0
B: Körperfortbewegung beim Fahren mit Muskelkraft	+	---
Fahrweg (nur bei B, sonst 0)	+	0
Arbeitsorganisation / Zeitliche Verteilung A oder B	+	2

Ergebnisse

Wenn weibliche Beschäftigte x 1,3

2 **Zeitwichtung** x **Summe Merkmalswichtungen:** 21 = M 42 x 1,3 W 54.6

Anhand des errechneten Punktwertes und der folgenden Tabelle kann eine grobe Beurteilung vorgenommen werden:				
Risikobereich		**Belastungshöhe***	**a) Wahrscheinlichkeit körperlicher Überbeanspruchung b) Mögliche gesundheitliche Folgen**	**Maßnahmen**
1	<20 Punkte	gering	a) Körperliche Überbeanspruchung ist unwahrscheinlich b) Gesundheitsgefährdung nicht zu erwarten	Keine
2	20 – <50 Punkte	mäßig erhöht	a) Körperliche Überbeanspruchung ist bei vermindert belastbaren Personen möglich. b) Ermüdung, geringgradige Anpassungsbeschwerden, die in der Freizeit kompensiert werden können	Für vermindert belastbare Personen sind Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sinnvoll.
3	50 – <100 Punkte	wesentlich erhöht	a) Körperliche Überbeanspruchung ist auch für normal belastbare Personen möglich b) Beschwerden (Schmerzen) ggf. mit Funktionsstörungen, meistens reversibel, ohne morphologische Manifestation	Maßnahmen zur Gestaltung und sonstige Präventionsmaßnahmen sind zu prüfen.
4	≥100 Punkte	hoch	a) Körperliche Überbeanspruchung ist wahrscheinlich. b) Stärker ausgeprägte Beschwerden und / oder Funktionsstörungen, Strukturschäden mit Krankheitswert	Maßnahmen zur Gestaltung sind erforderlich. Sonstige Präventionsmaßnahmen sind zu prüfen.

* *Die Grenzen zwischen den Risikobereichen sind aufgrund der individuellen Arbeitstechniken und Leistungsvoraussetzungen fließend. Damit darf die Einstufung nur als Orientierungshilfe verstanden werden. Grundsätzlich ist davon auszugehen, dass mit steigenden Punktwerten die Wahrscheinlichkeit einer körperlichen Überbeanspruchung zunimmt.*

Figure A.38 Second page of the conducted KIM risk assessment method regarding the carrying of a waste bag activity.

Erweiterte Leitmerkmalmethode zur Beurteilung und Gestaltung von Belastungen bei Körperfortbewegung (LMM-KB-E)

Arbeitsplatz / Teil-Tätigkeit:	Carrying of the Waste Bag		
Zeitdauer des Arbeitstages:	8:30 h	Beurteiler:	Dominic Wälti
Zeitdauer der Teil-Tätigkeit:	10	Datum:	

Beschreibung der Teil-Tätigkeit

For the calculation of the time weighting factor:

Average amount of waste collection sites per day = 38 (from Excel Sheet)
Average amount of slit containers per collection site = 2
--> 76 waste bags in average per day

Observed distance to carry: 5m < x < 10m
Estimation of walking speed = 3.6 km/h = 1 m/s
--> Estimation of the required time to carry 1 bag for 5m = 5s
--> Estimation of the required time to carry 1 bag for 10m = 10s
--> Average required time = 7.5s

Total amount of time: 76 * 7.5s = 570s = 9.5 min

Figure A.39 Third page of the conducted KIM risk assessment method regarding the carrying of a waste bag activity.

baua: Bundesanstalt für Arbeitsschutz und Arbeitsmedizin

PDF-Formular zur belastungsartspezifischen Zusammenfassung der Beurteilungen mit den Leitmerkmalmethoden über verschiedene Teil-Tätigkeiten eines Arbeitstages (LMM-Multi-E)

Bezeichnung des (typischen) Arbeitsplatzes / Arbeitstages:	Die Beurteilung ist gültig für:		
Waste Collection Site	Männer ✓	Frauen ☐	Beide ☐

Übersicht der LMM-Beurteilungen aller Teil-Tätigkeiten eines Arbeitstages

k Lfd. # Import	LMM Belas-tungs-art (LMM)	T_k Bezeichnung der Teil-Tätigkeit	t_k Reale Zeit-dauer [min]	ZW_k Zeit-wichtung [Pkt.]	I_k Intensität = Summe der Merkmalswich-tungen [Pkt.]	$PW_k = ZW_k * I_k$ Punkt-wert pro Teil-Tätig-keit [Pkt.]	$PW_{k:\ extrap.\ 8h}$ Hochrechnung der Belastung durch eine Tä-tigkeit dieser Art auf 8h [Pkt.]
Bsp.	*MA*	*Polstern*	*240*	*4*	*12*	*48*	*96*
#01	KB	Carrying of the Waste Bag	10	2.0	21.0	41.2	216
#02	HHT	Waste collection / Pick-up	33	4.1	20.5	84.1	288.3
#03	HHT	Slit Container Emptying	26	2.3	22.5	51.8	180.8
#04	GK	Throwing the Waste Bag	6	1.6	30.0	49.4	308.7
#05	GK	Pushing / Pulling of Bulky Waste	1	1.0	28.0	28.1	288.1
#06	HHT	Lifting of Bulky Waste	2	1.0	29.0	29	213.9
#07	---	---	0	0.0	0.0	---	---
#08	---	---	0	0.0	0.0	---	---
#09	---	---	0	0.0	0.0	---	---
#10	---	---	0	0.0	0.0	---	---
#11	---	---	0	0.0	0.0	---	---
#12	---	---	0	0.0	0.0	---	---
#13	---	---	0	0.0	0.0	---	---
#14	---	---	0	0.0	0.0	---	---
#15	---	---	0	0.0	0.0	---	---
#16	---	---	0	0.0	0.0	---	---
#17	---	---	0	0.0	0.0	---	---
#18	---	---	0	0.0	0.0	---	---
#19	---	---	0	0.0	0.0	---	---
#20	---	---	0	0.0	0.0	---	---
#21	---	---	0	0.0	0.0	---	---
#22	---	---	0	0.0	0.0	---	---
#23	---	---	0	0.0	0.0	---	---
#24	---	---	0	0.0	0.0	---	---

Zusammenfassung über den gesamten Arbeitstag pro physische Belastungsart

LMM	Physische Belastungsarten	Kumulative Zeitdauer t_{LMM} [min]	Anzahl Teil-Tätigkeiten pro LMM n_{LMM}	PW_{LMM8h} über alle Teil-Tätigkeiten [Punkte]	Risiko-bereich
HHT	Heben, Halten und Tragen v. Lasten	61	3	104.1	4 - hoch
ZS	Ziehen und Schieben von Lasten	0	0	---	---
MA	Manuelle Arbeitsprozesse	0	0	---	---
GK	Aufbringen von Ganzkörperkräften	7	2	51.9	3 - wesentl. erhöht
KB	Körperfortbewegung	10	1	41.2	2 - mäßig erhöht
KH	Körperzwangshaltungen	0	0	---	---
nb	Nicht beurteilte Teil-Tätigkeiten	0	0	---	---
alle	**Gesamter Arbeitstag**	78	6	**---**	**---**

Datum		Unterschrift	

Figure A.40 Interactive form for assessing multiple Key Indicator Methods (only available in German).

Appendix B

B.1 Needs-Metrics Matrix

Need No.	Need Category	Need
1	Forces	The device exhibits robustness and stability during operation, withstanding substantial forces
2	Material	The device is shielded against fluid intrusion
3	Material	The materials of the device exhibit resistance to strong cleaning detergents
4	Recycling	The device is engineered for extended operational longevity
5	Forces	The device is resistant to vibrations and external impacts
6	Assembly	The apparatus is securely and efficiently attached to the transport vehicle
7	Safety	The apparatus can be operated without necessitating entry into the cargo space
8	Safety	The objects to be loaded are secured during the lifting process
9	Ergonomics	The physical and mental strain on the user during the lifting process is minimal
10	Forces	The apparatus possesses the capability to elevate heavy objects irrespective of their nature
11	Kinematics	The apparatus is capable of loading heavy objects in an acceptable amount of time
12	Ergonomics	The apparatus can be operated by a single user
13	Forces	The apparatus possesses the capability to elevate large, unwieldy objects
14	Ergonomics	The apparatus can be operated with minimal manual interventions
15	Ergonomics	The apparatus can be deployed with ease
16	Ergonomics	The apparatus can be stowed with simplicity
17	Ergonomics	During periods of non-utilization, the apparatus does not obstruct other activities
18	Assembly	The apparatus does not cause collisions during the unloading process
19	Material	The apparatus is built out of lightweight materials
20	Assembly	The positioning of the apparatus complies with all regulations set forth by the Swiss Road Traffic Office
21	Assembly	The apparatus is located either within the interior of the cargo space or on the undercarriage of the vehicle
22	Assembly	Access to the device is unobstructed
23	Maintenance	The device can be easily detached from the transport vehicle
24	Maintenance	The device can be easily cleaned
25	Costs	The costs of production and assembly are subject to the established boundaries of the company

Metric No.	Metric	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	Young Modulus of Parts (E-Modul)	x																								
2	Stability of the apparatus during utilization	x																								
3	Resistance of the apparatus to liquids		x																							
4	Resistance of the apparatus against corosity			x																						
5	Operational lifespan of the apparatus				x																					
6	Resilience of the apparatus to environmental shocks					x																				
7	Tensile strength of the attachment						x																			
8	Shear strength of the attachment						x																			
9	Torsional strength of the attachment						x																			
10	Frequency of user ingress into the cargo space during a working day							x																		
11	Extent of security of the load attachment								x																	
12	Mental well-being of the user while operating the apparatus									x																
13	Incidence of user sick days attributable to work-related influences									x																
14	Available lifting force of the apparatus										x															
15	Duration required for loading a heavy object into the transport vehicle											x														
16	Number of users required to operate the device												x													
17	Maximum loadable volume capacity													x												
18	Number of steps required for the user to operate the apparatus														x											
19	Required time for apparatus deployment															x										
20	Number of steps required for the user to deploy the apparatus															x										
21	Required time for apparatus stowage																x									
22	Number of steps required for the user to stow the apparatus																x									
23	Potential time loss due to obstruction of other activities																	x								
24	Number of collisions or contacts during unloading																		x							
25	Total mass of the apparatus																			x						
26	Minimum distance of the apparatus from the ground while driving																				x					
27	Extent of rearward extension of the apparatus while driving																				x					
28	Adequacy of the apparatus stowage																					x				
29	Accessibility to the apparatus																						x			
30	Required time to access the apparatus																						x			
31	Required time to detach the apparatus from the transport vehicle																							x		
32	Required time to clean the apparatus																								x	
33	Material costs																									x
34	Production and assembly costs																									x

Figure B.1 Needs-metrics matrix.

B.2 Target Product Specifications

Metric Number	Corresponding Need Number	Category	Metric	Importance	Units	Marginal Value	Ideal Value
1	1	Forces	Young Modulus of Parts (E-Modul)	*****	GPa	>70	≥210
2	1	Forces	Stability of the apparatus during utilization	*****	Subjective	>3	5
3	2	Material	Resistance of the apparatus to liquids	****	IP-Rating	IP55	IP66
4	3	Material	Resistance of the apparatus against corosity	****	μm/year	1	<0.1
5	4	Recycling	Operational lifespan of the apparatus	**	years	>5	>10
6	5	Forces	Resilience of the apparatus to environmental shocks	****	Subjective	>3	5
7	6	Assembly	Tensile strength of the attachment	*****	N	>2575	>4415
8	6	Assembly	Shear strength of the attachment	*****	N	>2575	>4415
9	6	Assembly	Torsional strength of the attachment	*****	N	>1288	>2207
10	7	Safety	Frequency of user ingress into the cargo space during a working day	*****	Number	≤1	0
11	8	Safety	Extent of security of the load attachment	****	Subjective	≥3	5
12	9	Ergonomics	Mental well-being of the user while operating the apparatus	*****	Subjective	4	5
13	9	Ergonomics	Incidence of user sick days attributable to work-related influences	****	days / year	<5	0
14	10	Forces	Available lifting force of the apparatus	*****	N	≥735	981
15	11	Kinematics	Duration required for loading a heavy object into the transport vehicle	***	s	<600	120
16	12	Ergonomics	Number of users required to operate the device	*****	Number	2	1
17	13	Forces	Maximum loadable volume capacity	*****	m^3	≥3	4.5
18	14	Ergonomics	Number of steps required for the user to operate the apparatus	***	Number	<10	<5
19	15	Ergonomics	Required time for apparatus deployment	***	s	<120	<60
20	15	Ergonomics	Number of steps required for the user to deploy the apparatus	***	Number	<5	≤2
21	16	Ergonomics	Required time for apparatus stowage	***	s	<120	<60
22	16	Ergonomics	Number of steps required for the user to stow the apparatus	***	Number	<5	2
23	17	Ergonomics	Potential time loss due to obstruction of other activities	*****	s	<300	0
24	18	Assembly	Number of collisions or contacts during unloading	*****	Number	<2	0
25	19	Material	Total mass of the apparatus	*****	kg	≤200	<100
26	20	Assembly	Minimum distance of the apparatus from the ground while driving	*****	m	≥0.375	≥0.4
27	20	Assembly	Extent of rearward extension of the apparatus while driving	*****	m	<1	0
28	21	Assembly	Adequacy of the apparatus stowage	*****	Subjective	>3	5
29	22	Assembly	Accessibility to the apparatus	**	Subjective	>2	5
30	22	Assembly	Required time to access the apparatus	**	s	<90	<35
31	23	Maintenance	Required time to detach the apparatus from the transport vehicle	*	min	<60	<30
32	24	Maintenance	Required time to clean the apparatus	**	min	<10	<3
33	25	Costs	Material costs	****	CHF	<1500	<1000
34	25	Costs	Production and assembly costs	****	CHF	<4000	<3500

Table B.1 Target product specifications for the given metrics.