PART 2

Engineering the System around Humans

CHAPTER 7

Data Collection and Task Analysis

THIS CHAPTER PROVIDES:

- A structure and quick checklist approach for gathering data in any workplace improvement project.
- The basics of task analysis so that the analyst gains a clear idea of the intended and/or current operations, in order to select a scope for improvement.
- Hierarchical task analysis (HTA).
- Tabular task analysis (TTA).

How to cite this book chapter:
Berlin, C and Adams C 2017 *Production Ergonomics: Designing Work Systems to Support Optimal Human Performance.* Pp. 127–138. London: Ubiquity Press. DOI: https://doi.org/10.5334/bbe.g. License: CC-BY 4.0

WHY DO I NEED TO KNOW THIS AS AN ENGINEER?

If the authors of this book were to characterize ideal engineering work in a single word, it would be: structured. In the study of production systems, we are constantly striving to balance a large number of considerations and parameters that we want to optimize at the same time. Without a structured way of doing this, it is quite possible to not only miss many opportunities for improvement, but also to overlook losses of efficiency and productivity that could have been fixed if they had only been identified in time. Sometimes, there are conflicting optimization goals in the same system, and without a structured way to identify them, there is a risk for technical design improvements that actually end up making other aspects worse.

To avoid this, the engineer needs a structured way to describe what is happening in the workplace; especially when observing human behaviour, it is helpful to have methods that can show the difference between *intended* work procedures, and how things are really done.

When we are able to break down a job into tasks, we can see (and describe) very clearly when things are going as they should, and where specific steps involve actions that we can improve. A good task breakdown clarifies two things: what we want to do and what we are actually doing.

WHICH ROLES BENEFIT FROM THIS KNOWLEDGE?

The *system performance improver* needs to collect data in a way that allows comparisons of before and after states. Also, for this role in particular, exact knowledge of how tasks are carried out – and *meant* to be carried out – is essential information in order to target improvement actions effectively. This chapter supplies ideas for the various ways that exist for collecting work environment and work data, and how to ethically and efficiently gather data from humans and about humans as they work.

Likewise, the *work environment/safety specialist* may be well served by a good grasp of task analysis, in order to make the process of data collection efficient. Many of the ergonomics evaluation methods presented in Chapter 8 require specific measurements and surveying of qualitative as well as quantitative data. From a time and effort perspective, knowing ahead of time what type of data is important to make a workplace assessment (using appropriate equipment) helps this role avoid "overcollecting" data and spending time analysing unnecessarily.

Before carrying out any workplace improvement project, it is crucial to have a clear and structured idea of what conditions make up the current state of the workplace. There are a lot of factors to take in when assessing a workplace; as evidenced in Part 1 of the book, the human capacity for good work performance is influenced by very many different inputs and internal responses in the body and mind. In order to not get overwhelmed or waste time wondering which aspects to take into account, workplace improvers may decide to limit their scope to just examining one or a few isolated aspects – but this is seldom the best approach, since optimizing just one aspect at a time can have unintended effects on other performance factors. When the work environment is to be analysed for the first time, or the first time in a long time, it pays to have an approach for a holistic assessment of the workplace. We will in later chapters look at ergonomics evaluation methods specifically, but additional gains and improvement ideas may come from looking at work environmental physical factors, psychosocial and teamwork aspects, and available cognitive support.

The following three phases are necessary to conduct a holistic assessment of workplace ergonomics:

- Data collection
- Task breakdown
- Ergonomic evaluation

While the results obtained from using methods provide a good indication of where changes should be made, ultimately these methods are only instruments, and the responsibility to draw conclusions, make decisions, changes and recommendations is down to you, the production engineer.

Having a basic knowledge of both the strengths and weaknesses of each method is key when deciding which one will be used to conduct an evaluation.

7.1. Data collection involving humans

To design effective and healthy workplaces, there is a need to understand the current state of the workplace and its associated tasks. The systematic gathering of this necessary information is known as data collection, which is done to answer a question – in our case, identifying work tasks with a high chance of causing injury. Knowing how to choose methods for the collection of data is the first step in conducting a successful and valuable study. Regardless of the type of data collection method being used there are a number of best practices that should be followed:

- Be structured.
- Be systematic.
- Be ethical and respectful towards your human participants.
- Be ready to handle (analyse) your data.
- Be ready to present what your data says and express how dependable it is.
- Truthfully present any limitations there may be to the relevance of your findings.

7.2. Data collection approaches

There are two main approaches towards data collection involving humans; a quantitative approach, which seeks to measure and quantify, or a qualitative approach, which seeks to understand processes, reasons and interdependencies. Deciding which one to use is very dependent on the nature of your

research goal. However, it is counterproductive and wrong to automatically think that "qualitative" is synonymous with "subjective"[1], and that "quantitative" is synonymous with "objective"[2]. This is a misconception, but there is also an easy explanation to why it arises.

A qualitative approach is exploratory, answering questions of "how?" and "why?" (which is fully possible to do in an objective fashion). To a high degree, qualitative data collection involves interaction with people (e.g. interviewing and observing them), and is used for initial learning about previously unknown behaviours, defining new thought concepts, and recognizing trends and relationships between events. Typically this approach enables richer, detailed, in-depth answers to be obtained, but due to the time it takes to use qualitative data collection methods, such studies tend to involve small sample sizes/fewer people. If the aim is to learn about the nuances and variations of an unknown area of knowledge, a qualitative approach is suitable.

On the other hand, quantitative studies are suitable for examining relationships between previously well-described concepts and measurable changes in status. It is very important in quantitative method to be precise about what is being measured, so that there cannot be multiple interpretations of the results. This approach is more numbers-driven, as the aim is to measure and quantify, answering questions of "what?" or "how many?" As a result, answers to quantitative questions tend to be very brief, entirely avoiding explanations of why and how.

Quantitative methods have four main modes:

- **Census:** obtains data from every member of a population
- **Sample survey:** obtains data from a subset of a population (a sample), in order to estimate population attributes "well enough"
- **Experiment:** a controlled study in which the researcher attempts to understand cause-and-effect relationships by deliberately manipulating inputs and influencing factors
- **Observational study:** Like experiments, observational studies attempt to understand cause-and-effect relationships, but the researcher deliberately avoids manipulating any of the events

To obtain valuable quantitative results, the concept or theory being measured needs to have a scale by which it can be counted. Because the aim is to examine exact relationships between changes in quantity, the results are dependent on a large sample size (in the hundreds or thousands to be statistically significant), for the purpose of generating statistics that can indicate how relevant the theory is for the population being studied. However, statistics can also be carried out on the basis of data that is not objective in nature – opinion surveys are an example of this.

7.3. Carrying out a research study involving humans

When conducting data collection there are three key phases:

- Setting up the study
- Carrying out the actual data collection
- Analysing and presenting the data

In any study involving humans, a basic level of ethical standards is that of *informed consent,* i.e. all participants should be informed about the purpose of the study, what is expected of their involvement,

and how any collected data will be handled afterwards. Participation should be voluntary (with consent given in documented form) regardless of the nature of the study (observation, experiment, interviews, etc.), so participants should also be informed of the option to say no and decline participation. The study should also ensure that no humans will be harmed or have their personal data compromised by any of the activities or how the data are handled post-collection. If a study is carried out in an organization (such as a university), there may be an ethics board who must screen the study plan and approve it before it is permitted to go on.

These phases can be broken down more specifically into 12 steps:

1. **Define the overall goal of the research** – Are we collecting data and analysing it in order to map/describe? To define? To visualize? To quantify?
2. **Determine the type of research question for the study** – Is the area well defined or undefined; should a quantitative or qualitative study be conducted?
3. **Determine the scope, time frame and sample** – What limitations exist? Time frame available and time each activity will take, geographical or cultural boundaries, etc. Will a random, purposive or convenience sample be used?
4. **Determine stop criteria** – When has enough data been collected?
5. **List ethical considerations** (usually regarding confidentiality) – Respect participant's privacy and inform them of exactly what you are going to do with their data. Depending on your organization's requirements, present the study design to an ethics board for approval.
6. **Choose your collection method and tools –**
   Methods:
   - ***Observations:*** An attempt to gain an unprovoked understanding of the task at hand while observing people's behaviour. In *think aloud* observations the participant talks out loud, explaining their reasoning and thought process while completing a task.
   - ***Interviews/focus groups:*** Suitable for in-depth qualitative studies with few participants, can be structured, semi-structured or unstructured. Try to avoid yes or no answers, which will stop the flow.
   - ***Questionnaires/surveys:*** Mainly used to quantify and measure different occurrences, which can be made into statistics. Answers are often presented on a scale. Some brief free-text responses may be possible to collect, but are sometimes difficult to interpret correctly due to lack of context.
   - ***Case studies***: A specific context and event is studied in detail, to gain rich understanding.
   - ***Document studies:*** Existing documents (e.g. at companies) are studied and interpreted.

   Tools: camera, audio recording device, measuring equipment (tape measure, goniometer, weigh scales, etc.), stopwatch, checklist, estimation scales.
7. **Make a structure for your data collection –** How are you going to store and manage your data (e.g. by date, theme or participant)?
8. **Recruit or select participants –** This can be a time-consuming process, since participation must be voluntary. Participants must be informed of the purpose of the study and their part in it, and be informed of how the collected data will be handled. To boost participation, recruiting can often involve incentives (common examples include offering snacks and beverages or tokens of appreciation such as gift vouchers or movie tickets).

9. **Pilot test the data collection and tweak –** Use a small sample to test the method, and if necessary make modifications to the setup or questions before using a large sample size.
10. **Carry out the collection** – Ensure equipment is working and keep results well structured.
11. **Analyze the data –** "Let the data speak" and find meaningful trends, patterns or relationships within or between data sets.
12. **Present your findings** – Present findings together with limitations (such as sample size, time constraints, sample or environmental preconditions).

7.4. Task breakdowns

When studying how humans react to their work environment and the tasks they are required to carry out, utilizing a *task analysis* (Annett and Stanton, 2000) can provide a systematic working description of the task. Such an analysis provides accurate information of how tasks are performed in reality, which can be compared with how tasks should be performed and/or how tasks are perceived to be performed. In task analysis, a detailed description is established of the working task and all its necessary sub-tasks, showing how all the tasks are interconnected at various levels. This approach can be used to predict difficulties, evaluate performance and identify risks.

The analysis starts by establishing what the overall goal of the task is. Once we have broken down the overall task into sequential chunks, it is possible to isolate certain postures or motions that, if left unchanged, could contribute to long-term damage or MSDs. The necessary information to draw up a task analysis can come from interviews, observations, manuals or past experience. Task analysis has been extensively developed in research, particularly in connection with cognitive ergonomics and engineering, but we provide a short overview of the basics in this book hoping to encourage workplace designers to include evaluation of tasks in their coverage of finding improvement potentials.

7.5. Hierarchical Task Analysis (HTA)

A hierarchical task analysis (HTA; Annett, 2003) is task analysis method that provides an extensive description of all the necessary tasks to achieve a main goal in a hierarchal structure. Although terminology may vary somewhat, the following terms are normally used to identify different aspects of the task at various levels when conducting an HTA:

Glossary of HTA terminology

GOAL	External task resulting in a verifiable change of state, such as "making coffee" or "assembling a [product]"
TASKS	Activities necessary to achieve goals, sometimes using a device. Also called "sub-goals" (e.g. by Stanton, 2006)
SUBTASKS	Components of tasks
OPERATION	Simple task performed, lowest-level single action

DEVICE	Tool, machine or technique appropriate for achieving goals
PLAN	Number of tasks or actions linked into a sequence and describing rules and dynamics

These terms can be visualized in a hierarchical structure as shown in Figure 7.1.

In theory, it is possible to keep breaking down all the tasks until an exhaustive detailed list is established, right down to "sending nerve signals to muscle". However, such detail is rarely useful for engineering purposes, so it is necessary to determine the "stop criteria" for the degree of detail necessary. Knowing when to stop is just as much part of the process as identifying the subtasks is. It is okay to only expand the relevant tasks you are interested in and stop others at a higher level. Typically you stop decomposing when it becomes no longer relevant for the subsequent analysis. When visualizing a HTA, putting a solid line under the box shows that this is the deepest level of detail chosen for that specific task or operation.

How to carry out an HTA

A more formalized procedure for carrying out an HTA is described by Stanton (2006), in the form of the following steps (adapted from Stanton, 2006; p. 62–64):

1. **Define the purpose of the analysis**
   (e.g. system design, developing personnel specifications, analysis of workload, etc.)
2. **Define the boundaries of the system description**
   (i.e. which people and equipment will be considered in the analysis)
3. **Try to access a variety of sources of information about the system to be analysed**
   (This is in order to assure and validate the accuracy of the HTA; may include observation, interviews, expert consultation, manuals, simulation, etc.)

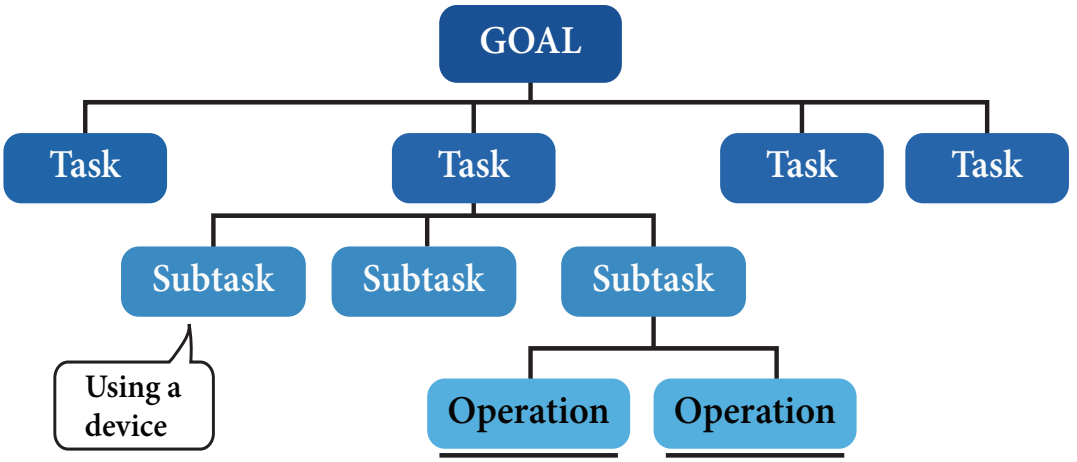


Figure 7.1: HTA structure.
Illustration by C. Berlin.

4. **Describe the system goals and sub-goals**
   (What is to be done? To what performance standard? Under what conditions?)
5. **Try to keep the number of immediate sub-goals under any super-ordinate goal to a small number (aiming for 3–10)**
   (Although there are exceptions, about 3–10 sub-goals are appropriate; if there are more, the analyst should consider whether some of these can be grouped into a super-ordinate goal to clarify the task overview.)
6. **Link goals to sub-goals, and describe the conditions under which sub-goals are triggered**
   (This is where plans are formulated to guide the sequence and iterations between the specified sub-goals. Plans indicate which conditions trigger a sub-goal, when the purpose is fulfilled and the next step is to be taken.)
7. **Stop re-describing the sub-goals when you judge the analysis is fit for purpose**
   (The level of description depends on the purpose of the analysis, so when to stop is up to the analyst – and is certainly easier if it is known who will use the information and how.)
8. **Try to verify the analysis with subject-matter experts**
   (Verification with experts is important to make sure the analyst has interpreted the system goals and operations correctly, and can add the benefit of transferring ownership of the analysis to the experts)
9. **Be prepared to revise the analysis**
   (As described in Stanton (2006 p. 64): "The number of revisions will depend on the time available and the extent of the analysis (…)". This may mean that several iterations are required to make the HTA accurate. Stanton (ibid.) continues: "It is useful to think of the analysis as a working document that only exists in the latest state of revision.")

HTA can be applied to a wide variety of work tasks, due to its flexibility in scope. Figure 7.2 shows an HTA where the overall goal is to unload a car.

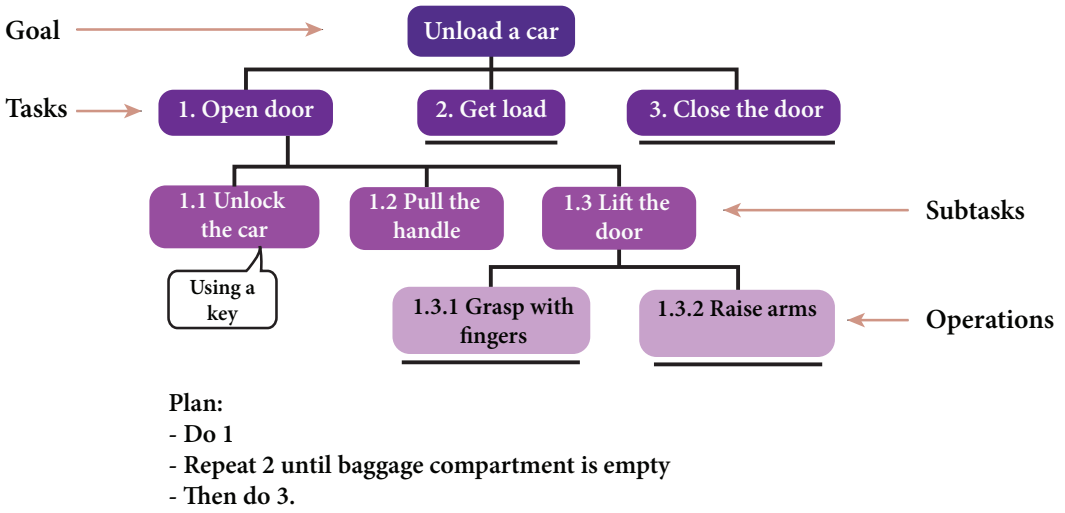


Figure 7.2: HTA Example – unloading a car.
Illustration by C. Berlin.

In this example, it can be seen that the analyst identified that the human needs to grasp the door handle with their fingers to open the door, but stopped going into further detail (note solid line under the operation box) about how many fingers will be used and which specific muscles will contract, as this is hardly necessary for understanding or analysing (or improving) this task.

7.6. Tabular task analysis (TTA)

It is also possible to visualise the same operations and tasks in a tabular form. The previous example of unloading a car could also be represented as in a table as shown in Table 7.1.

A task analysis can be an effective way to gain an overview of all the necessary tasks and operations involved with achieving the overall goal.

Once you have an idea of how tasks are intended to be (or are currently) carried out in a workplace, you have a basis on which to state your improvement goals and a way to focus and delimit your intervention efforts. In this way, you can be effective and efficient in your proposals, and clear in your communication about them towards other stakeholders.

Table 7.1: TTA Example – unload a car.

0	Unload a car
1	Open door
1.1	Unlock the door
1.2	Pull handle
1.3	Lift door
1.3.1	Grasp with fingers
1.3.2	Raise arms
2	Get load
3	Close door

Study questions

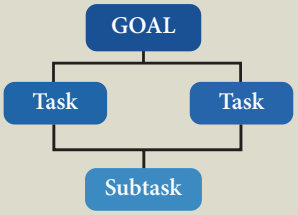
Warm-up:

Q7.1) When performing a study on humans, what are some basic ethical requirements on the work of an engineer or researcher?

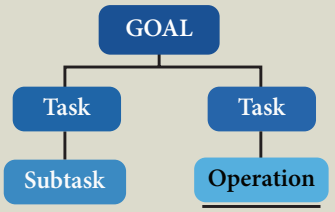
Q7.2) For the purposes of workplace improvement, what is the difference between an observation and an experiment?

Q7.3) Why are the following HTAs incorrect in principle?

a)



b)



Look around you:

Q7.4) Think of an everyday multiple-step task with a clear overall goal – like making a cup of tea or borrowing a book from the library – and try to perform a HTA on it. Can you determine the order in which steps are carried out, any necessary repetitions until the desired outcome is reached, and determine a lowest level of breakdowns (operations) for each step?

Connect this knowledge to an improvement project

- At the start of any workplace improvement project, it is crucial to understand the purpose and goals of what is done in that workplace. Alongside an observation and interview, a task analysis can help to form a basis for structured discussions about where and during what task risks are occurring; it also facilitates follow-up of whether interventions addressed the right target problems.
- The knowledge in this chapter can be used to plan time spent at worksite visits to investigate potential improvement potentials efficiently and comprehensively.
- The approaches described here allow for a separation of data collection (e.g. using recording devices) and data analysis, so that not all work needs to be done on-site where there is a risk of disrupting on-going work.

Connection to other topics in this book:

- Some ergonomics evaluation methods (Chapter 8) are task-oriented and it is sound practice to be able to identify the circumstance in which a particular posture, force or time exposure occurs. It is also easier (thanks to an awareness of overall goals for a task) to determine the reason for the risk – it may have to do with achieving a particular level of quality or performance speed.
- From an economical perspective (Chapter 11), it is wise to carry out a task breakdown to determine whether particularly crucial tasks that add great value (e.g. due to high demands of precision, quality and/or speed) are also associated with ergonomic pitfalls that risk being a chronic cause of unnecessary costs due to injuries, inefficiencies and scrap.

Summary

- A structured approach to understanding a workplace provides a dependable foundation for identifying and addressing improvement potentials.
- A work task can be broken down into elements to aid in analysis and identify risk areas, using a task analysis method.
- A number of methods are available for data collection and analysis, some of which are theoretically based while others actively involve workplace stakeholders.
- Using a combination of workplace observation, interviews and task analysis helps to give the workplace improver (and many other stakeholder roles) a good overview of what is meant to be done in a workplace, and at which points in the task-to-operations sequences there are ergonomic risks.
- Although the groundwork above may be considered time-consuming, it greatly facilitates discussions of where to direct intervention efforts and new design solutions, bringing them down to an appropriate level of precision. It also facilitates follow-up by pinpointing whether interventions and investments are appropriately targeted in scope to solve identified problems.

Notes

[1] Subjective data put the interviewee's personal perception, opinion and experience into focus; generally the answers are only possible for the asked person to verify (e.g. how they prioritize tasks, how much pain they are experiencing or how they perceive their workload).

[2] Objective data is possible to verify in an impersonal manner. This includes historical documentation, numbers, measurement from instruments, previously known facts, etc. (e.g. the temperature variation in a room over time or measured forces).

7.7. References

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