



## Perspectives on recycling centres and future developments



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### ABSTRACT

The overall aim of this paper is to draw combined, all-embracing conclusions based on a long-term multidisciplinary research programme on recycling centres in Sweden, focussing on working conditions, environment and system performance. A second aim is to give recommendations for their development of new and existing recycling centres and to discuss implications for the future design and organisation. Several opportunities for improvement of recycling centres were identified, such as design, layout, ease with which users could sort their waste, the work environment, conflicting needs and goals within the industry, and industrialisation. Combining all results from the research, which consisted of different disciplinary aspects, made it possible to analyse and elucidate their interrelations. Waste sorting quality was recognized as the most prominent improvement field in the recycling centre system. The research identified the importance of involving stakeholders with different perspectives when planning a recycling centre in order to get functionality and high performance. Practical proposals of how to plan and build recycling centres are given in a detailed checklist.

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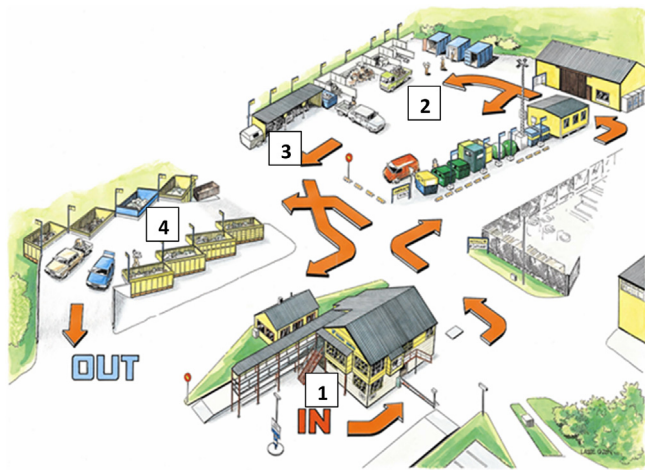
### 1. Introduction

The importance of a sustainable environment is generally recognized (McKinsey Global Institute, 2011; Radjijev et al., 2014), considering ecological, economic and social aspects (Josimović et al., 2015). Swedish waste management has undergone radical changes during recent decades. The handling of waste is complex, with many different actors involved. New laws are regularly introduced regarding the treatment of waste; which products are to be recycled; how they should be transported; and who is responsible for collection and storage of the collected material (Schultz, 2000). This leads to ongoing changes in how waste is handled, and has increased the demand for alternatives to landfilling such as material recycling, biological treatment and incineration with heat recovery.

At present, most household waste is recycled in Sweden and the share being landfilled has decreased to 0.7% (Avfall Sverige, 2014), compared to 34% on average for EU (Eurostat, 2013). A growing volume of waste, nearly 185 kg per inhabitant per year, is collected at recycling centres. These are manned drop-off facilities, where the users can bring, sort and throw away items e.g. large-sized, hazardous, and electrical waste. The waste is placed in large containers, cages and small containers (Fig. 1). Kitchen waste is not allowed. Well performing recycling centres, being very early in the recycling chain, are key to the subsequent steps in waste processing (Engkvist et al., 2004; Woodard et al., 2004). However, their performance has scarcely been investigated. The rapid growth of recycling, hastened by several new laws (Government Bill, 1993; SFS, 2001; EU Directive, 2002/96, 2003; Eurostat, 2013; European Commission, 2012), has mostly focused on environmental factors, but rarely taken the work environment or economic aspects into consideration. Thus, the work environment has often been shaped without conscious planning, and workers have had to adjust to the situation (Alvarez de Davila and Antonsson, 2001). Sometimes a recycling centre is built in one corner of a landfill, or on a small area with a few containers and no possibilities to expand when needed, e.g. with new laws concerning recycling of products. Due to the rapid

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**Fig. 1.** An example of a spread out recycling centre with an office/personnel building (1), area for garden waste (2), hazardous waste (3), a small and narrow container area, (4) and crossing traffic flows (modified from Sundin et al., 2011). The container area is often as here, built so that cars are driving up on a ramp. Thereby, the waste could more conveniently be disposed of in the lower placed large containers (4).

expansion of the recycling sector, there are challenges for the recycling system related to the following three fields: working conditions, environment and system performance. The research reported below has integrated social, economic and environmental aspects in order to make recommendations on sustainable systems for recycling in the future.

More detailed information about how recycling centres are organised in Sweden can be found in Engkvist (2010), Engkvist et al. (2011) and Sundin et al. (2011).

### 1.1. Aim

The overall aim of this paper is to draw combined all-embracing conclusions based on a long-term multidisciplinary research programme on recycling centres in Sweden, focussing on working conditions, environment and system performance. A second aim is to give recommendations for the development of new and existing recycling centres and to discuss implications for the future design and organisation.

## 2. Methods

A multidisciplinary research programme focussing on recycling centres was organised by a research group representing the disciplines of ergonomics (J Eklund, Engkvist, Hemphälä), safety (Engkvist), environmental management (M Eklund, Krook) and manufacturing engineering (Björkman, Sundin). In addition, 10 PhD and Master students worked in the programme. In total, seven studies were performed over a 10 year period. The researchers took the initiative to the research, got research funding for, in total three projects by VINNOVA, a Swedish governmental research agency. The detailed research questions were specified in close cooperation with representatives from the waste and recycling branches, in particular when designing two new recycling centres. The research included studies regarding: 1) a problem and system overview; 2) reported occupational injuries; 3) field studies including observations; 4) questionnaires and interviews at recycling centres (Table 1); 5) interviews with downstream actors; 6) development of equipment; and 7) training material for the industry and design recommendations for new recycling centres.

The researchers collaborated in developing the research

instruments in order to assure the multidisciplinary research approach. All questions from the four disciplines were brought together in one instrument addressed to each group of participants, making it possible to collect information from each individual on one occasion. In total 10 instruments were developed, in which 614 questions/aspects were covered. The development and conduct of the tests and experiences of the use of the instruments are described in detail in Engkvist et al. (2010). Validation tests along with the quality of the collected data, and experience from the data collection showed that the instruments and methodology used were suitable for their purpose. In total 868 datasets were collected by the 10 different instruments covering more than 433,000 responses. The data collection, target group, type of instrument, number of respondents among, employer, employees and users, and the response rate are shown in Table 1.

In study 1, semi-structured interviews were conducted covering the steps in the waste management chain from household waste to reuse, material recycling, incineration, or landfill. As recycling centres were identified as having a key role, they were the focus in the following research studies (Engkvist et al., 2004). Study 2 investigated reported occupational injuries among employees at recycling centres, based on official statistics (Engkvist et al., 2011).

In study 3, data were collected in field studies from employees, managers and users at 16 recycling centres, using both questionnaires and interviews. The 16 recycling centres visited were selected from different regions and catchment areas, their number of potential users and the year of their construction. These recycling centres were located across Sweden and they had their own unique layout and different sizes (Sundin et al., 2011). Data were collected from the employees concerning work tasks, physical and psychosocial working conditions and activities at recycling centres using questionnaires, followed by structured interviews to gain a deeper understanding of these aspects. The purpose of the data collection from users was to assess their activities and opinions about the recycling centres and characteristics of the waste brought. The users asked to participate were chosen at random before their arrival at the recycling centre. They were interviewed or asked to fill in a questionnaire after disposing of their waste but before leaving the recycling centre. Users were also observed, without disturbing or intruding on them, concerning their activities, behaviour and the characteristics of their waste (Engkvist et al., 2010). The number of employees and users who were interviewed, or who filled in a questionnaire in connection with the different studies is shown in Table 1. Data collected from managers assessed their practices and operational conditions, e.g. number of employees, training of personnel, information campaigns, opening hours, financial aspects, etc. All 16 managers were interviewed and all recycling centres were assessed for risks and hazards.

In study 4 the questionnaires for employees were expanded with questions concerning the plant and sent to 26 additional recycling centres, covering all counties in Sweden (Engkvist, 2010; Engkvist et al., 2010; Eklund et al., 2010). In study 5, nine downstream actors were interviewed who processed and treated the collected waste regarding their quality requirements and business interactions with recycling centres: five fuel suppliers of wood waste, two scrap metal merchants and two stakeholders of waste paper (Krook et al., 2008; Krook and Eklund, 2010b). Further, in study 6, a lack of equipment for the employees, e.g. a tool suitable for picking up incorrectly disposed waste was identified, and as a result, such a tool was developed (Sundin, 2009b).

During the study period the researchers cooperated with a municipality-owned company that was responsible for collecting and handling waste, reported in study 7. Two new recycling centres were planned and built, and consecutive results from the study were discussed and considered in the planning process. The second

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