NewInnoNet

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TERMINOLOGY & ABBREVIATIONS

Terminology

Best available techniques

The most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole:

- "techniques" includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;
- "available" means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;
- "best" means most effective in achieving a high general level of protection of the environment as a whole.

Best practice — Best practice is a technique or methodology that, through experience and research, has been proven to reliably lead to a desired result and can be used as a benchmark.

Bottleneck — A phenomenon where the performance or capacity of an entire system is limited by a single or small number of components or resources[1].
In this methodology the bottlenecks are defined as factors that limit the performance and efficiency of the value chain and thus prevent or limit the move towards near zero-waste value chain and circular economy.

Collection — Includes source separation, collection and transport until pre-sorting or recycling plant.

Criterion — The criteria define what issues are taken into account when the effect of removing a bottleneck is evaluated. The criteria are selected in the MCDM process so they reflect the motives of the work and are completely but non-redundantly describing the effects of removing a bottleneck.

Decision maker (DM)

A member of the expert panel (see Expert panel). DM's preferences are elicited during the MCDM process.

Dismantling/

[1] Wikipedia

Disassembly — Systematic separation of components, parts or a group of parts from a product by physical means.

Expert panel — The Multiple Criteria Decision Making (MCDM) process in WP2 is panel based. The Expert panels consist of several decision makers (DMs). The Expert panels' preferences are elicited in a workshop organized for each value chain. The members of each Expert panel are selected in the MCDM process for each value chain.

Manual processing — Includes manual pre-separation, dismantling and disassembly stages of the waste value chains.

Material recovery — Any recovery operation, excluding energy recovery and the reprocessing into materials which are to be used as fuel[2].

Mechanical processing — Mechanical processing and sorting stages, including shredding/ crushing and process stages where elements or compounds in a mixture are separated through mechanical rather than manual and chemical means.

Measure — A measure indicates how well removal of a bottleneck would perform in a criterion.

Multiple criteria decision making (MCDM) — Multiple criteria decision making consists of problem formulation and choosing the best alternative based on decision maker's (DM's) preferences on performances in selected criteria. The DM's value functions for every criteria measure must be defined or elicited. Similarly the criteria weights that describe the DM's preferences over the importance of the different criteria are elicited.

Post sorting — Treatment of the processing residues in order to separate valuable substances or to enable valorisation of the residual materials.

Prioritization of bottlenecks — The objective of MCDM analysis in WP2. When a bottleneck is prioritized, its removal will be discussed in the New_Innonet roadmap. Selection and definition of bottlenecks are not included in the MCDM.

Recycling — Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations[3].

Recovery — Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy[3].

[2] Proposal for the amendment of waste directives, 2014/0201 EC, withdrawn
[3] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste

Refined metal/plastic/ mineral streams
: Specified quality raw materials produced either from secondary materials or integrated refining of both primary and secondary raw materials.

Refining
: The final processing stages aiming for removal of impurities from raw materials (may include (thermo)chemical processing stages).

Registration/deregistration
: Product intake in official product database/register/Removal from register.

Remanufacturing
: *A* process of disassembly and rebuilding of a product to specifications of the original manufactured product using a combination of reused, repaired and new parts. It requires the repair or replacement of worn out or obsolete components and modules.

Reuse
: Any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.

Secondary metal/ plastic/mineral streams
: Recycled material streams that either need further purification or are suitable only to lower grade uses.

(Thermo)chemical processing
: Thermochemical and chemical processing stages, including pyro- and hydrometallurgical processing, thermochemical conversion, etc.

Value chain
: A high-level model of how businesses receive raw materials as input, add value to the raw materials through various processes, and sell finished products to customers[4].
In this methodology report value chain defines the mass, energy and monetary flows in the waste management system. Three best practice value chains are included in the project scope: ELV, ICT, and plastic packaging waste.

Value chain analysis
: Analysis of the value chain for material, energy and monetary flows

Abbreviations

ARN	ARN Holding B.V
ATF	Authorised Treatment Facility
CSA	Coordination and Support Action
D	Deliverable
EC	European Commission
ELV	End-of-Life Vehicles
EPR	End of Product Responsibility
ETP	European Technology Platform

[4] Investopedia, http://www.investopedia.com/terms/v/valuechain.asp

EUPC	European Plastics Converters
FMCG	Fast-moving consumer goods
FP	Framework Programme
GHG	Greenhouse gases
H2020	Horizon 2020 The EU Framework Programme for Research and Innovation
ICT	Information and communications technology
IETU	Institute for Ecology of Industrial Areas Poland
IHOBE	Ihobe, S.A.
IVL	IVL Swedish Environmental Research Institute
M	Project month (e.g. M6 stands for month 6 of the project)
NGO	Non Governmental Organisation
PMT	Project Management Team
PNO	PNO Consultants B.V.
PRE	Plastics Recyclers Europe
PRO	Producer responsibility organisation
R&D	Research and Development
S&T	Scientific and technological
SINTEF	STIFTELSEN SINTEF
SIRA	Strategic Innovation and Research Agenda
SME	Small and medium enterprises
TD	Technical Document
Tecnalia	Fundacion Tecnalia Research & Innovation
VGW	Van Gansewinkel Groep B.V.
VITO	VITO nv
VTT	VTT Technical Research Centre of Finland Ltd
WEEE	Waste Electrical and Electronic Equipment
WM	Waste Management
WP	Work package
WPFP	Waste plastic food packages
WPP	Plastic Packaging Waste

1. OVERVIEW OF THE DELIVERABLE

WP:	WP2
Task :	Task 2.1 Development of a common methodology for bottleneck analysis
Title :	Common methodology for bottleneck analysis

1.1 OBJECTIVES OF THE PROJECT AND PROJECT CONTEXT

1.1.1 Objectives of the project

The main objective of the NEW_InnoNet project is to mobilise stakeholders towards building a circular economy by developing and reinforcing solid foundations for building the European Near-Zero Waste Platform through:

- Set-up and maintain near zero-waste stakeholder platform
- Analyse selected waste streams and develop innovation roadmaps per waste stream
- Develop an integrated near zero waste strategic research and innovation agenda
- Stakeholder mobilisation and interaction.

1.1.2 Objectives of the WP2 analysis

The aim of this report is to define common methodology to be used in WP2 Analysis of value chains to identify best practices & bottlenecks. The objectives of the WP2 are

- to create an overview of existing best practices and in-the-pipeline technologies and approaches
- to identify and prioritize bottlenecks in the automotive (ELV waste), electronics (waste electronic equipment, WEE) and plastic packaging (plastic packaging waste, WPP) value chains.

The bottlenecks are defined as factors that limit the performance and efficiency of the value chain and thus prevent or limit the move towards near zero-waste value chain and circular economy. The bottlenecks can be either technical or non-technical (financial, organisational, political, legislative or societal) in nature.

The significance of the limiting factors will be analysed based on the economic value, improvement of resource efficiency and strategic value/ benefit that could be attained by removal or reduction of the limiting factors (bottlenecks). Multiple criteria decision analysis will be applied for prioritization of the bottlenecks.

The results of the analysis per value chain will be cross-linked to define commonalities between the bottlenecks, so that uniform solutions applicable to several waste streams could be identified.

Thus the overall objective of the work of WP2 is to create the basis for roadmaps and strategic research and innovation agenda by evaluating where and how the change towards near zero-waste value chains and circular economy can be made by overcoming the major bottlenecks of technical and non-technical nature.

The key stages of WP2 analysis methodology are presented in the figure 1 below. A more detailed description of each stage can be found in the following chapters.

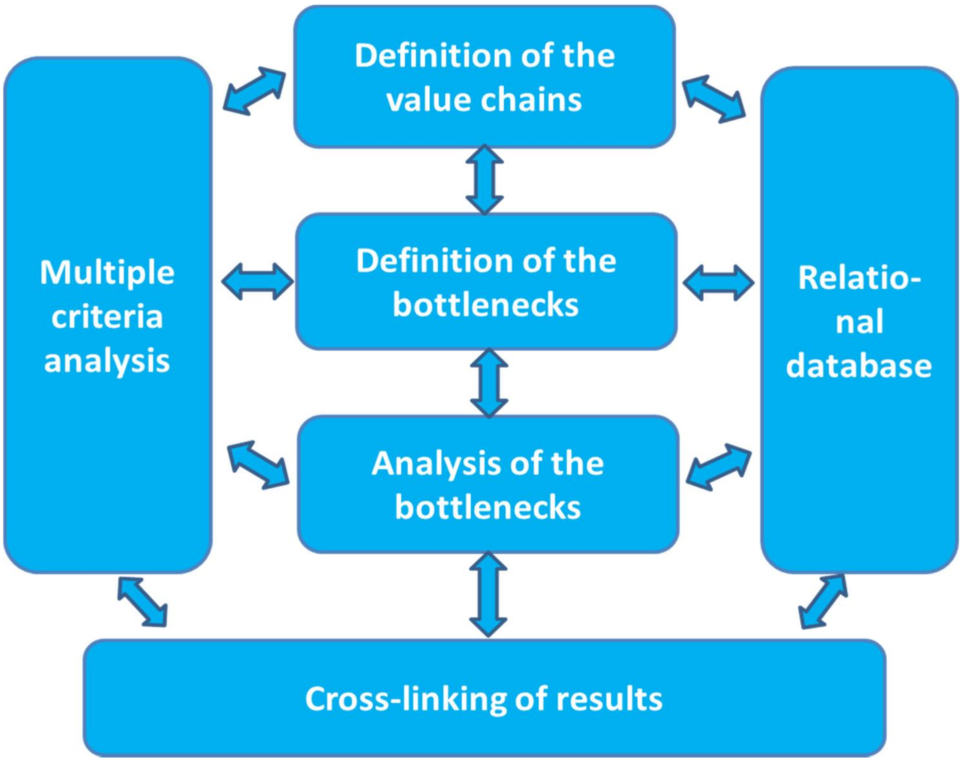

Figure 1 Description of the stages of analysis of the best practice value chains to identify best practices and bottlenecks

2. Definition and analysis of the best practice value chains

The aim of this stage is to define the current best practice value chains in order to enable identification of bottlenecks limiting the performance in the chain and to enable collection of data that is needed for analysis and prioritisation of the bottlenecks. The definition of the chain defines the borders of the analysis and the focus area of the database on current and future best practice technologies and solutions.

2.1 Description of the value chains

The value chain covers the waste handling operations from waste discarding and collection to processing stages which prepare reusable parts or raw materials fulfilling the specifications of the prevalent manufacturing processes. The key actors in different stages of the chain are identified, as well (collaboration with WP1). The product manufacture and use is not main focus of the analysis, but it cannot be totally excluded, because the technical and economic feasibility of the waste chains is dependent on the product development and design. In addition, more efficient recycling or re-use might have impacts on the need of primary materials (for example on price and availability of primary materials, environmental impacts of sourcing and processing of raw materials or savings of non-renewable resources), thus having impacts at the beginning of the chain.

Because there are differences in the operations chains between the three target sectors (ELV, WEEE, Plastic packaging waste), the general value chains can be adapted to the sector needs by the task teams. It is, however, recommendable that the general framework is similar in all the three value chains.

The proposal for general description of the value chains is presented in Figure 2.

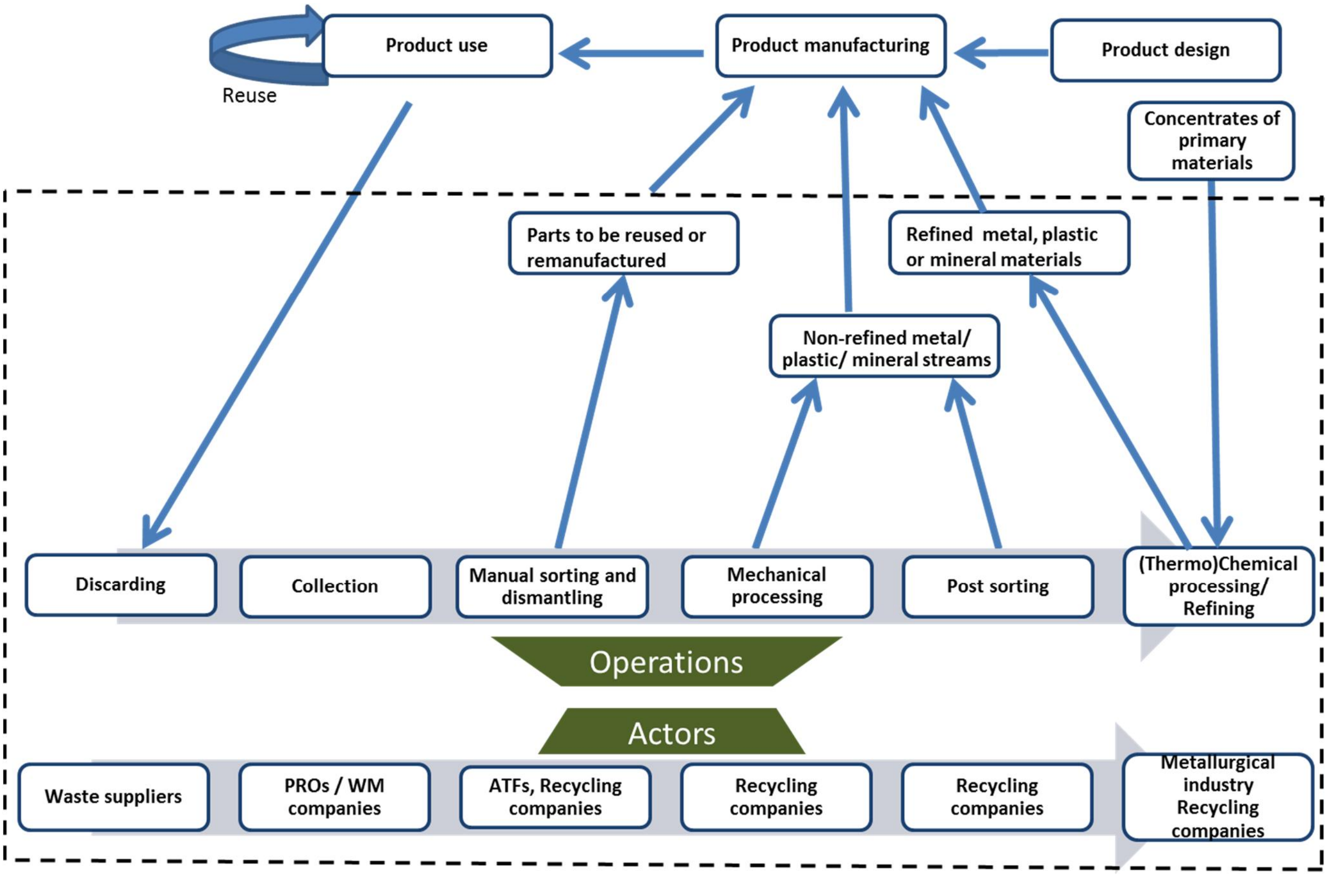

Figure 2. Description of the operations, actors and products in the waste value chain. The analysis is focused on the activities inside the dashed borders.
PRO = Product Responsibility Organisation; ATF = Authorised Treatment Facility; WM = Waste Management

2.2 ANALYSIS OF THE VALUE CHAINS

The aim of this stage is to produce background data for the analysis of the effects of removing of the bottlenecks. This analysis is dependent on the project objectives and it should produce the numerical values or estimates of the criteria that will be used in the prioritisation of the bottlenecks for the roadmap work, analysis of future use cases for the integrated R&I agenda and strategic R&I agenda (WP3, WP4 and WP5) and research and innovation agenda (WP3 and WP4). The proposal for the bottleneck analysis criteria is presented in the Chapter 3.4.3. The definition of the criteria may need to be an iterative process and if needed the list of criteria will be updated based on the input of the three value chain task groups.

The following methods are proposed to be used in the analysis of value chains:

- Material and energy flow analysis of the chain, including analysis of quantities and materials that are currently not recovered;
- Analysis of the potential (total) value of the material input;
- Analysis of the quantities and value of materials and parts that are currently recovered.

3. DEFINITION OF BOTTLENECKS

A bottleneck may have different type of definition based on the context it is referred. Within New_InnoNet bottlenecks are defined as factors that limit the performance and efficiency of the value chain and thus prevent or limit the move towards near zero-waste value chain and circular economy. The bottlenecks can be either technical or non-technical (financial, organizational, legislative or societal) in nature.

Bottlenecks need to be described comprehensively and explicitly in such manner that the effect of it on the whole performance of the value chain can be detected. Therefore, in the bottleneck description a deeper definition of, which things cause the bottleneck (cause and effect) are requisite. In order to perform multiple criteria decision analysis, each bottleneck need to be measured against the selected criteria (economic etc..., see Ch 4.3.4). In the process of identifying the bottlenecks, a need may emerge to make changes to these criteria, as they should describe the bottlenecks as well as possible. It should be noticed that initial bottleneck (idea) may actually be composed of several individual bottlenecks which need to be all treated and described separately. The description should at least include:

- The name of the bottleneck;
- Reason why it is a bottleneck;
- Description of what effect it has on the value chain (objectives of the project)

In the following section suggestions for definition of a few selected bottlenecks from each value chain are described.

3.1 EXAMPLES OF BOTTLENECKS

In the following, selected examples of bottleneck definition and reasoning behind the bottlenecks are presented. The bottlenecks have been selected from the preliminary lists of bottlenecks provided by the bottleneck analysis task leaders.

<u>WEEE (ICT)</u>

<u>Bottleneck: Continuous change of composition of the products</u>

- Due to the fast development and upgrading of electronic devices, the WEEE stream changes even within product groups. The laptop purchased 3 years ago is not the same as the laptop sold today;
- As a result of the fast change, no individual product centric dismantling/separation process can be developed. This leads to lower recovery rates of certain materials when the process is optimized to miscellaneous feed.

<u>Bottleneck: Damage due to rough handling as waste</u>

- Waste can be handled roughly in logistics or within processing at which time electronic components may disengage or break and generate losses. On the other hand some operational parts of devices may break through rough handling and therefore lose their functionality (-> increase in entropy);
- Reuse or remanufacturing is complicated or hindered by damage of components in the dismantling stage. In some cases rough handling of waste may damage waste products resulting to losses especially of components containing valuable metals;

- The bottleneck could be described more aligned. One bottleneck on disengage of components through rough handling within dismantling or other processing stages. Second bottleneck on the loss of functionality of components/part through rough logistics;
- Since the bottleneck description is not unambiguous (disengage of components vs. loss of functionality), the bottleneck should be redefined.

ELV

Bottleneck: lowering amount of vehicles available for recycling → the actual bottleneck should be defined as export of old vehicles outside Europe

- Old vehicles are exported outside the Europe which reduces the amount of vehicles entering recycling process. Besides loosing potential input material for recycling, final treatment of these vehicles may not be environmentally sustainable. In addition, due to the low feed amount, higher treatment investments cannot be carried out which may lower the recovery of valuable materials.

Bottleneck: Material recycling of ASR light fractions (foams, minerals) not economically feasible (only competing on disposal tariffs, like gasification, incineration and landfilling).

- The bottleneck should be defined more unambiguously since current version consists of several individual bottlenecks even though they may all affect the recycling;.
- For example one bottleneck could be the disposal tariffs.

Plastics

Bottleneck: Promotion of landfilling

- Plastics are still lost to the landfill in significant quantities since it may be still the easiest and cheapest way to treat plastics;
- Are there actually two bottlenecks behind the initial bottleneck?
  1. The cost of landfilling does not cover the actual cost to the society (low cost of landfilling)
  2. Legislation promotes landfilling (this might affect also on the first bottleneck suggestion);
- As a result, the bottleneck should be redefined.

Bottleneck: Not high recycling rates in some countries→ the actual bottleneck should be defined more specifically. In this case no reasoning why recycling rate is low has been made

- New definition required.

3.2 Template for bottleneck descriptions

In the Table 1. below a template proposal for the bottleneck descriptions is presented.

Table 1 Template for bottleneck descriptions.

Name of the bottleneck	Reason for the bottleneck	Effect of the bottleneck on the value chain
Low cost of landfilling (plastics)	The costs of landfilling do not cover the actual cost to the society.	Potential valuable material for recycling is lost to the landfills.
Bottleneck 2	...	...
Bottleneck 3	...	...
...	...	...
Bottleneck n	…	…

3.3 Identification of commonalities between value chains

The lists of bottlenecks will be shared between the task groups to identify the common bottlenecks. The commonalities will be analysed and descriptions of bottlenecks harmonised, if possible (Input to Task 2.5 Cross-linking of the results).

4 PRIORITIZING OF THE BOTTLENECKS USING MULTIPLE CRITERIA DECISION MAKING METHOD (MCDM)

4.1 OBJECTIVES OF THE MULTIPLE CRITERIA DECISION MAKING

Multiple criteria decision making (MCDM) is used as a part of WP2 work, in order to arrive at a list of prioritized bottlenecks which removal should earn special focus. During the MCDM, the significance of the limiting factors (bottlenecks) is analysed based on the economic value, improvement of resource efficiency and strategic value that could be attained by removal or reduction of the limiting factors. The MCDM process within WP2 is defined here and in the following chapters 4.3 and 4.4. The identification of the bottlenecks, although a part of WP2, is not within the scope of the actual MCDM process.

After the MCDM process, the results of the analysis per value chain will be cross-linked in WP2 to define commonalities between the bottlenecks, so that uniform solutions applicable to several waste streams could be developed. This is done in accordance to the overall objective of the work of WP2, to create the basis for roadmaps and strategic research and innovation agenda towards near zero-waste value chains.

4.2 THE BASICS OF MULTIPLE CRITERIA DECISION MAKING (MCDM)

In multiple criteria decision making, a set of alternatives are formally evaluated towards how they would fulfil a given objective. Common criteria are selected which act as measures how each alternative would perform. How these criteria are treated and used depends on the selected and applicable formal decision making method. How the alternatives, objective and criteria structure the decision making problem is also discussed in this chapter.

The decision analysis in the WP2 is dealing with a decision problem involving multiple criteria under certainty. Here, the criteria are under certainty because an explicit value rather than a probability distribution is given for a bottleneck's performance in each criterion. Moreover, the decision alternatives (i.e. which bottleneck to prioritize) are explicit. Possible formal decision methods could then include Multi-attribute value theory (MAVT), Analytic hierarchy process (AHP) and outranking methods such as ELECTRE.

MAVT builds on the axiomatization of decision maker's preferences (i.e. has a solid mathematical foundation). The decision maker's preferences are modelled as value functions. A value function $v_i^N(x_i)$ transforms any measured variable x_i (e.g. monthly salary or time it takes to commute to work) to a number representing its subjective value to the decision maker. Note, that the $v_i^N(x_i)$ is not necessarily linear. For instance, one might appreciate 1 000 €/month increase in salary more if the original salary is 2 000 €/month rather than 10 000 €/month.

Value is a measure of a preference under certainty. If the decision alternatives would have probability distributions over a given measured variable x_i, we would use the term utility rather than value and the corresponding formal decision making method would be Multi-attribute utility theory (MAUT).

In MAVT, the overall value of an alternative is calculated by using the additive value function:

$$V(x) = \sum_{i=1}^{n} w_i v_i^N(x_i)$$

Where

$V(x)$ is the overall value of an alternative,

$v_i^N(x_i)$ is the normalized value of a criterion measure of an alternative and

w_i is a weight given for a criteria.

When the performance of all alternatives have been assessed regarding each criterion, worst performance levels x_i^0 and best performance levels x_i^* are known for each criterion.

$$v_i^N(x_i^0) = 0$$

and

$$v_i^N(x_i^*) = 1$$

apply for the normalized value functions.

Criterion weight w_i reflect the increase in overall value when the criterion performance is changed from the worst level x_i^0 to the best x_i^*. The following equation applies for the criteria weighs:

$$\sum_{i=1}^{n} w_i = 1$$

Therefore, to use MAVT to arrive at the best decision once the problem is formulated, the value functions $v_i^N(x_i)$ first have to be defined. Secondly, the criteria weighs w_i must be elicited. Finally, the alternative with the highest overall value $V(x)$ should be chosen.

4.2.1 Structuring and defining the decision problem

A decision problem consists of an objective, a set of alternatives to choose from and a set of criteria with measures on how the alternatives perform.

Decision analysis begins by defining the objective and the alternatives.

Once the objective and the set of alternatives are clear, the selection of suitable criteria can begin. The criteria define what aspects are taken into consideration when the alternatives are evaluated, and must be in line with the objective of the decision analysis.

The criteria need to:

- reflect the objectives of the analysis and the effect associated with the consequences of each alternative;
  - The group of selected criteria should be minimal yet complete;
- be measurable or evaluable;
- be operational, meaning that it should be possible to judge each alternative against each criterion;
  - Decision maker's preferences of performance levels in a criterion should not depend on

performance in another criteria (i.e. preferential independence);
    - This should apply between all subsets of the criteria (i.e. mutual preferential independence);
    - Moreover, decision maker's preferences considering a change in a criterion performance should not depend on the performance levels in other criteria (i.e. difference independence);
- and avoid double-counting (in some cases double-counting may be justifiable).

4.2.2 Elicitation of value functions and criteria weighs

Value functions $v_i^N(x_i)$ describe decision maker's preferences of criteria performance, as the subjective value of a criteria performance x_i to a decision maker may not increase linearly from lowest to best available performance.

In order to capture also the level of preference in addition to order of preference between different criteria performances, indifference weighing should be applied. Bisection is one of such methods. In bisection method, the decision maker is asked to give a performance value between the worst and best performances in a criterion. He/she would have to prefer the change from the worst level to the given level just as much as the change from the given level to the best level. This process can be repeated between any two defined performance levels, every time improving the accuracy of the decision maker's value function on the criteria performance. Indifference methods can be applied on indiscrete criteria measures only.

Once the decision maker's value functions on the criteria performances have been assessed or decided upon, the criteria weighs w_i are elicited. Again, there are alternative methods that can be used in this stage and indifference methods such as the trade-off method should be preferred. In trade-off elicitation procedure, the decision maker is asked to compare two criteria at a time against each other and select imaginary performance levels that would result in two equally preferred alternatives.

4.3 MCDM METHODS AND DEFINITIONS

As mentioned previously, a formal multiple criteria decision making is used in WP2 in order to arrive at a list of prioritized bottlenecks which removal should be addressed in the NEW_InnoNet project. The decision problem to be solved is further defined in this chapter. The associated terminology is also defined.

The MCDM process in WP2 is described and defined in the following chapter 4.4. The terminology used is defined in the Chapter Terminology, page 3.

4.3.1 Selected MCDM methods

Panel based MCDM using MAVT is proposed to be applied in the WP2.

The Expert panel's preferences are taken as averages from the individual DM's preferences.

The value functions $v_i^N(x_i)$ are assumed to be linear between worst performance levels x_i^0 and best performance levels x_i^* for all criteria measures x_i.

To reflect the decision maker's preference between different criteria, the criteria weighs must be elicited. Again, there are several formal methods available. Methods should be preferred that tell how much a criterion is preferred over another, not just the order of preferences. Therefore, trade-off weighing is the selected elicitation method.

4.3.2 Objective

Objective for the MCDM in WP2 is prioritization of the bottlenecks that should be removed in the case value chains.

4.3.3 Alternatives

The decision alternatives consist of the removals of the identified bottlenecks. How the bottlenecks should be removed is beyond the scope of the MCDM process.

4.3.4 Criteria

The criteria for the MCDM must be selected so they describe the relevant aspects of the bottlenecks. As the bottlenecks are defined during the WP2 work, some iterative work will be needed to refine the criteria suggested here, based on input from the bottleneck analysis. The bottlenecks are defined based on the project goal and scope, and the criteria indirectly reflect these same goals, however. Therefore, the criteria presented here can also be guiding the bottleneck identification process outside the scope of the MCDM.

The criteria, their measures and interpretations used in the MCDM of WP2 are given in Table 2. To best describe the bottlenecks, the criteria were selected to cover the economic, environmental and material efficiency effects of the bottlenecks as follows:

- Economic: Lost value and additional costs due to the bottleneck;
- Material efficiency: Losses of metals and plastics duel to the bottleneck;
- Environmental: GHG emissions and release of harmful substances due to the bottleneck;
- Other: Technical and economic feasibility of removing the bottleneck

The list of final criteria will be updated based on the findings and input from the tasks working on bottleneck identification and assessment.

Table 2. The proposed criteria for the MCDM in WP2

Criteria	Measure	Interpretation
Lost value of materials or components	€/t feed	The value of the materials or components lost due to the bottleneck
Additional costs	€/t feed	Costs to the actor and society (in Europe) caused by the bottleneck (e.g. landfill or incineration costs)
Losses - metals	kg/t feed to the system	The quantity of metals lost due to the bottleneck
Losses – plastics	kg/t feed to the system	The quantity of plastics lost due to the bottleneck

GHG emissions	kg/t feed	Impact of removal of the bottleneck to the GHG emissions, including emissions avoided due to the reduced extraction and processing of primary materials
Release of harmful substances to the environment	kg/t feed	Impact of removal of the bottleneck to the release of harmful substances
Feasibility	A probability estimate, 0 (not possible) – 1 (certain)	How likely the bottleneck could be realistically removed within the next 5-10 years? The feasibility attribute is included in order to avoid assigning most value on alternatives that would have a high impact but would in reality be very difficult to attain technically, economically or even socially.

4.4 PRE-EXPERT PANEL MCDM PROCESS IN WP2

4.4.1 Criteria selection

The criteria that measure (describe) the effect of the bottlenecks to the performance of the value chain are defined during the pre-expert panel workshops and other meetings in WP2. The currently proposed criteria, along with their measures and interpretations are defined in chapter 4.3.4.

4.4.2 Performance evaluation

The criteria performance of each bottleneck is evaluated by the value chain WP2 tasks.

The value chains need to be analysed to produce either quantitative, semi-quantitative or qualitative information describing the consequences of each option. Task members and potentially selected external experts can be used to gather the needed information.

For the criteria presented in Table 2, following kind of information is needed to support the performance evaluation:

- A detailed description of the stages of value chain. This will be needed also for creating a data base with existing and on the pipeline technologies in another work package;
- Quantitative/semi quantitative material flow analysis to identify the material losses/material efficiency in different stages of the value chain (kg/t material fed to the system or percentage of the material lost);
- Quantitative/semi quantitative analysis of the value of lost material and the additional costs caused by the bottleneck (estimated value of lost materials/value chain stage, €/t; additional costs €/t);
- Analysis/description of environmental loadings (main emissions or sources of emissions focused on GHG and harmful substances);

- The feasibility of the alternatives is established by consideration of techno-economic (environmental and social) performance of the alternatives, including their regulatory environment, but ultimately based on expert opinion and dialogue.

A performance matrix is produced by value chain tasks based on the analysis; see the fictional example below in Table 3:

Table 3: An imaginary example of a performance matrix of the alternatives on the selected criteria.

Type of criteria	Material efficiency		Economic		Environmental		Other
Criteria	Losses of metals, kg/t feed	Losses of plastics, kg/t feed	Value of the lost material, €/t feed	Other costs, €/t feed	CHG emissions, kg/t feed	Release of harmful substances, kg/t/feed	Feasibility, probability
Bottleneck 1	210	90	5000	+++	+++++	++	0,5
Bottleneck 2	20	50	2000	+	++	++++	0,7
Bottleneck 3	40	50	900	+++	+++	++	0,2

4.4.3 Selection of the expert panel

The WP2 value chain tasks are responsible for forming the expert panels. The panels should ideally form of actual decision makers, although knowledge of the considered value chain is beneficial. The panels can include e.g. representatives of recycling and manufacturing industry, service and technology providers, governance bodies, financiers, NGOs, etc. The panels can each consist of up to 10 - 15 decision makers, enough to represent all stages of the value chains, if possible.

4.5 Expert panel workshops in the MCDM process of WP2

The weighing of the criteria will be performed in a workshop for each value chain by an expert panel. VTT will organise and facilitate the workshops in collaboration with value chain task members.

An expert panel workshop will preferable be held from lunch to lunch over two days in such a way that the alternatives are presented and the criteria interpreted during the afternoon. The actual decision making, i.e. weighing of the criteria will then be carried out during the next morning along with the critical interpretation of the results.

The work flow during the expert panel workshops will be guided according to the following chapters.

4.5.1 Presentation of the alternatives

The objective of the MCDM and the decision alternatives are presented to the panel members in the beginning of the workshop.

4.5.2 Interpretation of the criteria

The criteria measures' definitions are revisited and reformed during the expert panel workshop in order to direct the group of decision makers towards making comparable decisions.

The interpretation of the criteria has relevance on the independencies of the criteria. For instance, some measures of economic criteria are based on the same material flow, and therefore the measures are dependent. However, the criteria have different meanings in this decision making context compared to their stand-alone definitions. The different interpretations of economic criteria decouple the links and mutual preference independence is achieved.

4.5.3 Weighting of the criteria

Each panel member's preferences are determined by defining pair-wise trade-offs between most important criterion and other criteria.

The most important/preferred criterion is selected as a consensus among the panel members. Balanced importance of each other criteria are obtained as average of all panel members' preferences.

In trade-off weighing, the decision maker (DM) is asked to compare two imaginary alternatives (alternatives A and B). Alternative A has a freely selectable performance in the most preferred criterion and lowest available performances in other criteria. Alternative B has the highest available performance in another criteria (than the most preferred one) while the performances in all other criteria are on the lowest available level. The DM is asked to select a performance of alternative A in the most preferred criteria that would make the two alternatives equally preferred. This is repeated until arriving at the least preferred criteria. These elicitation questions produce ratios between the criteria weighs. As the weighs sum up to one, the weighs can be solved.

4.5.4 Interpretation of results

The criteria weights and measures are combined to determine the preference order of alternatives. This will be done by VTT during the expert panel workshops. Interpretation of the results with the expert panel is important factor to the quality of the MCDM, as the DMs can evaluate whether their preferences indeed are align with the final criteria weighs and the results.

4.6 Cross-linking of the results

The results of the bottleneck analyses for the different waste streams will be compared and commonalities between them defined. The information will be used as input for the development of the different roadmaps.

- Identification of commonalities between value chains, such as common project stages current technologies and approaches and future solutions (input to database);
- Identification of common bottlenecks between value chains, comparison of the bottleneck analysis and prioritisation results between value chains.

5 DATABASE

5.1 THE BASICS OF DATABASE

The database is a digital representation of the portion of the real world, objects, processes, behaviours, and relationships which exist in it. Every database problem can be solved in several ways. Sometimes, some solutions are better than others, but often two approaches lead to different solutions, none of which is better or worse. The database structure largely depends not only on the user's requirements, but also on the style of the designer. Some parts of designer activities cannot be formalized, so the quality and effectiveness of solutions depend on his intuition.

The primary purpose of the construction of the database is to fulfil all user requirements in the scope of future application. Therefore, the model may not describe all reality but can be a significant simplification of reality.

Database design consists of two main phases: logical and physical model. Logical model contains all descriptions of all information that will be stored in a database in a way in which man percept it. The physical model describes how data is stored and how it is accessed from the IT system point of view. The physical model is based on the logical one and is tailored to the specific requirements of the user not forgetting that data access has to be implemented in the most efficient way. The physical model includes the aspects of IT infrastructure owned by user. Changing or adding new requirements usually makes it necessary to change the physical model, although the logic model remains unchanged. Too many user demands often causes physical model to be inefficient - different requirements may be in contradiction with each other.

Creating a database is an iterative process. After the development of logical and physical model it is necessary to review the project together with the user and to get his comments or acceptance. All agreed proposals should be applied to the project.

5.2 SHORT DESCRIPTION OF THE AIMS AND CONTENTS OF THE DATABASE

The aim of the New_InnoNet database is to:

- Identify existing and in the pipeline technologies understood as practical application of technical or scientific principles to achieve a given purpose in the current best practice value chains (WP2) (e.g. sorting technologies, crushing technologies, etc.);
- Help identify the technological gaps to overcome the bottlenecks analysed under WP2;
- Support the roadmapping exercise in building the zero value chains under WP3 from the technological perspective;
- Serve as matrix for the ICT platform for clustering of technologies under WP4;
- Provide input for the development of the Strategic Research and Innovation Agenda.

Within the project a methodology, structure of the database and an ICT platform for collecting the data and clustering the technologies will be developed. The data to populate the database shall originate from the stakeholders and dissemination activities of the project.

The uniqueness of the approach to the database consists in the way the gathered data will be translated into information. The design of platform shall enable the users to get information on the availability of technologies (both commercially available and under development) to satisfy specific needs/issues identified as bottlenecks at the specific processes within a value chain. It shall also assist the users to configure new pathways with closed loops within the value chains addressed in the project or crossways (based on the roadmapping).

The starting point for the development of the database will be the definition of the targeted current best practice value chains, more precisely the identification of the specific processes (e.g. discarding, collection, sorting etc.) together with a list of technologies (in the meaning as mentioned above) at each of the value chains in which a utility value is added to the input material. A list of potential input and output materials for each of these processes will be required. This information will serve as a basis for identification of a list of technological solutions that refer to a given process together with the list of potential input and output materials.

As next step, outcomes from the analysis of the bottlenecks, especially of technological nature and these where the output material causes a problem due to applied technology. It will serve a twofold purpose:

- identify these processes in the value chains in which technologies are an obstacle including the feature of the obstacle, and
- processes and input/output materials that should be included in the value chain in order to enable the near-zero waste objective.

Next, based on the vision of the roadmaps developed under WP3 for each of the value chains, additional processes will be identified including input/output materials. These processes will be added to the processes already identified under WP2. The combined list of processes will become the basis for clustering of the technologies in WP4.

Based on this data a set of predetermined attributes lists for describing the technologies will be developed including:

- Process they address;
- Value chain / value chains to which they apply;
- Input material (materials) for which they apply;
- Output material

These attributes may be used afterwards as technical features for clustering the technologies.

5.3 Logical Model of Database

Designing logical model involves the determination of logical data structures necessary for gathering information from certain sources. This way of design (from the human point of view) allows the effective implementation of the model in close collaboration with the user. During the transition to the physical model it may be noticed that some elements in a logical model have been omitted or overlooked and must be added.

The database, in the context of the logic model, should be designed to ensure:

- data independence - a project logic should be independent of the application that will use the database and the infrastructure, because the logical model represents the way they are presented to the user, not how they are processed by computer;

- physical flexibility - the logical structure does not include performance requirements and is independent of the infrastructure - so it can be implemented anywhere, regardless of the database system;
- integrity - the logical model should identify data used in the system, system rules and relations. The model should cover the entire scope of the built system;
- user satisfaction - logical design is presented in a simple way, using easy to explain diagrams. They are user-friendly and can be shown to the user at every stage of design process. The project can be easily changed, often built on a sheet of paper, rather than using computer tools. It is important to work interactive with users.

Logical model should contain description of the data required by user applications with particular attention to what and where should be visible (views on the website, forms). As a supplement of database diagrams a data dictionary should be build.

To represent the whole system the entity-relationship approach can be used. With this approach entity-relationship diagram has to be designed. It visually represents all data relationships that exist in a system.

Entity is a general term that occurs in the design of databases that can be defined as some unit of classifiable data with relationships to other entities. Each data entity should appear as a noun in the list of sentences that define system functions. Many nouns appear in the sentences that are not entities. Only nouns that describe data that is meaningful to the system itself should be identified as entities.

During the logical model construction all the needs of the user must be identified. This process is carried out through interviews and surveys with all key users. Database design should take into account all their needs.

A typical process of building a logical model consists of:

- analysis of the system and its logic;
- identification of entities and relationships between them;
- identification of entities attributes;
- normalization of attributes;
- verification of the model in order to support all the required processes.

Database design should be preceded by an analysis of the system and processes to be managed. They should define both general and specific functions of the system. Each function should be described by a very simple single sentence. After identifying all the functions, the data that they require must be identified. This list will change dynamically along with the expansion of knowledge regarding the operation of the system.

These tasks can be accomplished through interviews with users and analyse of user-proposed forms and reports that will be supported and generated by the system. The user must determine through simple sentences goals of a forms and reports - 'who' achieves 'what'. This information helps to identify entities. This can be done applying the use-case methodology. The knowledge provided by the user is verified by the designer in terms of data integrity in the system, then corrected and presented to the user for evaluation. The reconciliation process of forms and reports continues until the satisfaction of both parties is achieved. Processes supported by the system can be illustrated using data flow diagrams.

The analysis should result in the creation documentation with a list of general and specific functions, data flow or hierarchy plus input-process-output diagrams and list of data elements.

The relationship combines two entities. It usually can be expressed as a verb. The database and relationships between entities can be described using simple sentences composed of subject, predicate and object only. Among relationships, there are three main basic types: one-to-one (1-1), one-to-many (1-M), and many-to-many (M-N).

Attributes are the smallest units of data that describes the entity or relationship. Each attribute has a value but the value may be null. Some attributes have special significance, these include primary and foreign keys that uniquely identify entities and are used for building relationships between them. These keys may be combinations of several attributes.

For identified attributes it is necessary to characterize their types and nullability. Also the dictionaries have to be prepared for descriptive data.

Having identified and characterized entities, relationships and attributes, normalization process can be carried out. Its aim is to create tables in Third Normal Form (3NF). Entities should consist of a primary key and attributes whose values are determined solely by the value of the primary key.

The final step of the project is the logical model validation and verification. In order to verify model the data flow tests should be performed for each process defined in the system. Access paths should be traced to cover all possible data access methods like read, create, delete and update.

5.4 PHYSICAL MODEL OF DATABASE

The system designer is responsible not only for the logical correctness in the database structure, but also for efficient data access.

Designing the physical model is the process of adjusting the logical model to the performance requirements. During this process has to be planned the best use of hardware and software assets.

Physical design is based on data structure diagrams. These diagrams visualise the manner in which entities are physically related to one another, while entity-relation diagrams show the logical connections. The data structure diagram also describes the storage characteristics of the data.

The process of building the model consists of following steps:

- creation of an initial data structures based on a logical model;
- identifying the performance requirements;
- evaluation and tuning.

Initial data structure will be built based on the DBMS available or selected by the user. In this environment a physical database as well as physical tables will be created. During the database creation some calculations concerning database size and its performance have to be done. Implementation details are closely linked to DBMS capabilities.

Each entity from the logical model is mapped one-to-one in the physical model, as well as each one-to-many or one-to-one relationship reflects physical connection. Each many-to-many relationship defined in the logical design must be converted to two one-to-many relationships. To achieve this demand each relationship must be replaced by entities generally having no attributes except foreign keys. Also in some technical or logical cases a self-referencing relationships have to be created or replaced by new entities.

Identification of performance and storage requirements should include: performance requirements for transactions, determination of how often transactions are executed and entities are accessed, determination of database entry points and number of entities occurring in each transaction.

Database evaluation should cover determination how the system will be affected by the concurrent execution of several transactions. Evaluation and tuning is iterative process with several optimization tasks. It includes eliminating unnecessary entities and relationships, adding and configuring indexes, splitting database file into several files and data stores, analysis and choice of proper triggers and constraints.

The final step is to review the database structure with users to ensure that the database will support all required functions.

5.5 IMPLEMENTING DATABASE DESIGN

Once the models are reviewed with user, all logical, storage and performance requirements are determined, the implementation phase may be started.

Naming convention has to be established as a first step of implementation process. Database tables and columns should have short, meaningful names. A good practice is to define and create schema groups. Typically all tables associated with the same general process are defined within one schema. Each entity have to be defined as table with its own name, list of columns including their characterization like data type or nullability and check constraints. For each table indexes and constraint statements have to be created. Some logical requirements make necessary to create some data views. Having all data structures, privileges for specific users or groups may be granted or denied. Usually it is combined with schema based approach.