The MatchMaker! System: Creating Virtual Eco-Industrial Parks 1997

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ABSTRACT
The virtual eco-industrial park alters the Kalundborg model by allowing firms that are not in proximity with one other to exchange material flows. Bechtel Corporation Research and Development, San Francisco, has studied the Kalundborg model and numerous other eco-industrial parks (EIPs) in order to assess the viability of industrial symbiosis (IS) on a grander scale. A world leader in engineering and design, Bechtel is frequently contracted to build and manage industrial parks on a large scale worldwide. Bechtel has had some success with a prototype virtual eco-industrial project in Brownsville, Texas. Existing material exchanges operate over regions and industries, providing services over the Internet and through books. These services use different material classification systems, making integration difficult.

Our team's project built upon the experience of Brownsville and the material exchanges by designing and creating a new system for matching materials flows. The system uses a material taxonomy which operates in a similar way to the standard industrial classification system (SIC) code hierarchy. The system, called MatchMaker!, is based upon a relational database, providing a path for future development.

MatchMaker! can be used by firms and local authorities to perform material flow analyses over wide geographical areas. Information from New Haven industries has been imported into MatchMaker! from a commercially available CD-ROM, but standard material flow data is insufficient to perform a regional matching exercise.

The next steps examined in this paper are the entry of standard SIC-based material flows into the database, enhancement of the material taxonomy, and eventual ownership of the product. Future visions include the ability to automatically map the material flows, a web-based database, and integration of local, regional, and national eco-industrial parks.

BECHTEL PROJECT

History

Industrial parks have long been utilized as a means for realizing economic advantage. By co-locating, enterprises can reduce the expenses of security, facility maintenance, and perhaps even permitting. Some industrial parks take the community idea a step further by adding a common cafeteria, reprographic facility, or mailroom to their list of common resources. In the typical scheme, however, industrial park members act as solitary individuals. By neglecting the community aspects of co-location, an enterprise may forego the economic advantages of a symbiotic relationship with its neighbors. Such industrial symbiosis (IS) among proximal facilities can provide opportunities for competitive advantage and environmental amelioration. As the evolutionary successor to industrial parks, eco-industrial parks (EIP) go one step further by linking local industries through a cooperative system of material and utilities exchanges.

The industrial community in Kalundborg, Denmark has progressively integrated about a dozen industrial members into an economically viable and environmentally-friendly system. Diverse enterprises have co-located in order to exchange a variety of materials and utilities that would otherwise have been lost or discarded. The paragon EIP, Kalundborg has proven that by "closing the loop," industries can gain competitive advantage, reduce their environmental liabilities, and improve their public image. Through this concerted waste minimization effort, society also benefits from improved economic conditions and reduced natural resource usage, waste generation, and pollution.

The Kalundborg model cannot easily be reproduced throughout the world. The microcosm at Kalundborg was created under a very specific set of political, economic, societal, and environmental circumstances. It is uncertain if and how the EIP would have developed under other conditions. Nevertheless, the Kalundborg scenario demonstrates the feasibility of exchanging utilities, information, and material streams through industrial cooperation.

Bechtel Corporation Research and Development has forseen a competitive edge in developing a tool that can identify IS possibilities in a complex industrial system. This tool could be used to methodically develop EIPs as well as improve the economic and environmental conditions of existing systems.

In its investigations, Bechtel questioned the necessity of co-location for IS to work. If co-location is a critical element of success, Bechtel argued, then the size and scope of an EIP will be limited to the physical size of the park. However, if some waste streams can cost-effectively support their transportation, then a "virtual" EIP (VEIP) could be constructed to include exchanges throughout a city, a region, or perhaps the world.

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The idea for a VEIP was first tested in the Brownsville Regional IS Project. Covering industries in the Brownsville, Texas and Matamoros, Mexico areas, the project provided the opportunity to explore the theory of IS planning throughout a region. Over several months, Bechtel conducted interviews of local area businesses to see what material streams were required or available for exchange.

These data were then assembled in a Microsoft (MS) Excel database. Although very limited in its functionality, Excel was useful as a rudimentary first-generation platform for validating a proof-of-concept model. Another database was constructed that included generic input and output stream data for a large variety of industrial sectors. The input data from existing facilities were then matched against local output data that resulted in a list of potential exchanges for the extant facilities. The matched streams could then be exported into Bechtel's proprietary systems optimization tool (PIMS) to demonstrate how the best solution would be achieved.

The local data were also matched to generic data in hopes of identifying specific industry types for which there might be symbiotic opportunity. By no means the exclusive factor, this local-exchange gap analysis could be included in a decision-maker's evaluation of siting a facility in the area.

Bechtel has envisioned applying this tool worldwide. In addition to Brownsville where key projects have developed such as a new port in Viet Nam, a light industry and airport project in the United Arab Emirates, and the Jubail Industrial Complex in Saudi Arabia. On a national level, Bechtel wanted to test the tool in an urban redevelopment project, and has discussed such a project with interested academic, community, government, and industrial partners to stimulate regional development through IS and IS-related strategic planning in New Haven and Connecticut.

Even with the emigration of some industry, Connecticut still boasts an extensive small-scale industrial base, in addition to a modest population of large manufacturers. In 1994, for example, the EPA processed about 1,000 forms for a total of 359 Connecticut facilities that were required to report Toxics Release Inventories (TRI) under the Clean Air Act Amendments of 1990. With a population of 3,275,000, the state ranked 19th nationally for total intrastate transfers to recycling of the 189 reported chemicals. On-site, almost 40 million pounds of chemicals were either combusted for energy recovery or otherwise treated. Off-site transfers for recycling, energy recovery, treatment, and disposal exceeded 35.6 million pounds. Since the bulk of these chemicals are typical industrial solvents (e.g. methanol, dichloromethane, toluene, etc.), it is distinctly possible that many of these and other "wastes" could serve as useful input streams to local area business.

Organizations known as "waste exchanges" sought to broaden the spectrum of materials available for exchange beyond those traded in formal markets and arranged for by brokers. Unlike the middle-men who often receive materials and resell them, waste exchange organizations serve only as information brokers helping generators and end users to find each other.

THE CONTEXT: EXISTING MECHANISMS

Waste Exchanges

Since the dawn of the industrial era, formal mechanisms have been employed to reclaim waste products and deliver them to end users who value them as commodities. Scrap yards, recycling centers, dealers, and brokers have historically served as middle-men, providing indirect linkages between generators and users of waste materials.

For some commodities, such as machinery and scrap metal, the middleman pays the generator for the waste material and then sells the material to an end user. For other commodities, such as chemical wastes and certain grades of glass and paper, the generator will pay the middle-man to accept the waste product rather than pay expensive disposal fees elsewhere. Sophisticated markets have developed for waste commodities such as scrap metal, paper, glass, cardboard, wood, rubber, and plastics. Market prices are reported in trade journals like the Recycling Times, and some exchanges are coordinated in formal markets such as the Chicago Board of Trade Recyclables Exchange.

In the mid-1970s, a new mechanism emerged to coordinate materials exchanges. Organizations known as "waste exchanges" sought to broaden the spectrum of materials available for exchange beyond those traded in formal markets and arranged for by brokers. Unlike the middle-men who often receive materials and resell them, waste exchange organizations serve only as information brokers helping generators and end users to find each other.

We spoke with the heads of several waste exchanges in the United States and Canada who describe their roles as collecting information about materials available from generators or wanted by end users and disseminating that information as widely as possible. Most waste exchange organizations follow a database model quite similar to the classified ads one sees in a local newspaper. Generators place ads for available materials into general categories such as acids, alkalis, solvents, metals, and plastics. End users can search the listings for materials of interest or place "wanted" ads for materials they are seeking.

About 15 waste exchanges across North America provide on-line catalogs searchable by category or keyword. While many of the on-line exchanges are accessible on the World Wide Web, a few are maintained as private computer bulletin board systems that must be dialed directly. Both the on-line exchanges and the off-line exchanges publish printed catalogs of materials available and materials wanted. Most of the exchanges allow for generators and users to place ads anonymously, but the exchange operators usually encourage participants to disclose their identities in the listings.

The majority of current waste exchange organizations are non-profits or quasi-governmental entities operating under the auspices of local departments of environmental protection. These exchanges tend to limit their geographic outreach to a single state or county. A small number of exchanges are owned and operated by industry groups such as the European Plastics Converters Association and by waste generators themselves such as Siemens of Germany.

Funding for most waste exchanges comes from government grants or incentive payments based upon the quantity of waste disposal averted by the waste exchange service. Additional revenue comes from fees paid by parties placing ads, subscription sales of the catalog or on-line service, and fees paid by generators or end users upon successful completion of a match.

Fragmented by region or by industrial sector, the current waste exchanges are ill equipped to take advantage of the opportunities for long-distance or cross-sector transfers. There has been some effort among the on-line exchanges to pool their listings, but the lack of standardization has been a stumbling block.

Limitations of Waste Exchanges

While waste exchange organizations have been quite successful at averting unnecessary disposal and encouraging symbiotic industrial relationships, the organizations face several limitations. Fragmented by region or by industrial sector, the current waste exchanges are ill equipped to take advantage of the opportunities for long-distance or cross-sector transfers. There has been some effort among the on-line exchanges to pool their listings, but the lack of standardization has been a stumbling block.

Arrowwood Associates, an Indiana-based consulting firm, has developed Arrowwood Market, a database system for managing waste exchange organizations. For a fee, Arrowwood pools the databases of multiple exchanges using the Arrowwood Market software and allows for long-distance matching. Relatively few waste exchanges are currently using Arrowwood Market, and it remains to be seen if it will emerge as the industry standard.

Since most waste exchanges group listings into large, general categories such as acids and alkalis, many potential end users have difficulty locating materials that may be of use to them. Listings may be hundreds of pages long, and some end users report that the search process is more trouble than it is worth. Some of the on-line services provide keyword matching and most of the other exchanges can perform simple keyword searches for people who phone with a specific request. This keyword searching, however, is frequently complicated by the lack of standardization of material descriptions in the listings. The Arrowwood Market software creates a small taxonomy with general categories such as oil or plastics and sub-categories such as PET or HDPE plastic. These categories are often still too general to permit an automated matching process.

The existing waste exchanges are poorly suited for proactive matching, co-location, or gap analysis. As the exchanges focus upon materials available and materials wanted, the databases are of no use in matching non-specified material flows. Exchanges are unable to match generators and end users for commodities such as steam or water. And because the exchanges do not track extensive flow information, they cannot proactively recommend potential matches based upon industry averages for firms that have not included their own materials listings.

Conventional EIPs

Providing economic advantages through proximal IS, EIPs entice responsible and interested industries to co-locate. The newly constructed system should be a well-balanced mix of businesses in which the aggregate input and residual streams of the assembled system are significantly lower than the sum of the disaggregated entities. Furthermore, previously unidentified dissipative waste streams, such as latent heat, non-contact cooling water, or pressurized steam, can similarly be exchanged to provide improved economic efficiencies while decreasing the consumptive reliance on natural resources.

Co-location, however, is not without costs. Existing companies that are considering participating in an EIP must take into account the costs of relocating to that particular site. Furthermore, the company will likely have to contribute to the capital costs of setting up an infrastructure to support the symbiotic activity. In addition to capital outlay, construction of this connectivity requires identifying and locking in specific tenants. The greatest enticement for joining the EIP is the competitive advantages offered through IS, so enlistment is difficult until a critical mass of willing candidates is assembled. Should a participating enterprise become defunct or simply choose to leave the EIP, the fragile business microcosm will suffer until a suitable replacement is found. Since the infrastructure does not generally lend itself to flexibility, it can be a formidable task to find a company that is willing to enter the community and who can fill the system's gap.

VEIPs avert many of the obstacles associated with conventional EIPs without detracting from the associated advantages. Most generally, a VEIP can be considered the evolutionary successor of material exchanges and conventional EIPs. Taking the best aspects of both constructs, VEIPs provide improved economic and environmental benefits without the constraints and limitations of the previous models.

Evidence supports the conclusion that the co-location aspect of conventional EIPs is advantageous. VEIPs have therefore been constructed to exploit the benefits associated with co-location while providing opportunity for more distant matching. Because some residual streams have inherent value that exceeds the cost of transportation (i.e. either the price density of the material is high or the scarcity of the material in the region is such that the price in the market supports the exchange), VEIPs can consider matches within any preselected radius. If the costs are justified, materials can be exchanged throughout a city, a region, or worldwide.

Where local exchanges may justify the capital costs of direct connectivity, exchanges at greater distances will require the use of current transportation modes. Although this added cost may reduce the likelihood of certain exchanges, the size of the VEIP community and its commensurate possibilities can dwarf the micro-economy of a conventional EIP. VEIPs also offer the advantage of modularity. After the critical mass of participants has been organized – a much easier challenge than the construction of a conventional EIP due to the larger area over which participants can be selected – additional firms and flow matches can be added one at a time. Other important benefits of VEIPs are: 1) allowing companies to disengage from the virtual community without economic penalty beyond lost opportunity, 2) providing greater varieties of possible exchanges, 3) lessening the reliance on individuals for system stability, and 4) not requiring high initial capital investment.

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THE VISION OF VIRTUAL EIPS

VEIPs can offer advantages to both private and public institutions. At the firm level, an existing facility can use the system to identify local companies which may benefit from an IS relationship. Matching input and residual streams, these firms find mutual economic benefit in an association that coincidentally reduces their burdens on natural resources and the environment. Companies also may find utility in the tool when siting a new facility. The user can provide the criteria for a search (e.g. "What regions of the country provide maximum opportunities for IS given my projected input and output streams?"), and the tool would output a list of regions and their associated potential matches. This output could then be exported to a Geographic Information System which would present the details graphically and assemble all other information relevant to the decision. Although many factors must be considered when locating a new business, this approach would assure that the differing opportunities for IS at each site would be included in the decision-making process.

City and regional development organizations can also benefit from a well-managed VEIP. By analyzing local businesses as an industrial system, public and private development organizations can identify specific industries that would benefit and would add benefit to the existing network. For example, a developer may use the tool to identify a sector gap and then proceed to set up an enterprise with private funds to exploit that opportunity. Similarly, an economic development organization could identify target industries to complement the existing installed base. Lastly, a city council might use the tool to identify IS possibilities for a specific company which it is trying to entice to relocate to the area. Either through direct development or through the promotion of external capital, organizations can employ VEIPs as an analytical and strategic tool for promoting economic opportunity.

In fifteen years, much of the world is likely to be connected through the World Wide Web or its progeny. Businesses throughout the world could subscribe to the MatchMaker! webpage and use its extensive regional and global databases to improve their resource efficiency. In fact, future versions of Netscape could be shipped with the site preinstalled as a bookmark.

As local VEIPs grow, they can continually update regional nodes which in turn communicate with the Local Area Node Collective Expert System (LANCES). This central processing unit could act as the global VEIP while providing the advantage of advanced expert systems integration. LANCES' "intelligent" elements learn with each new datum, providing the sub-networks with novel matches, improved hierarchies, and better predictive assessments. Inevitably, companies and governments will query local, regional, or global VEIPs in search of information essential to proper operational and strategic decision-making.

While typical waste exchange organizations can only help match generators and end users that are actively seeking one another, MatchMaker! can create proactive matches between firms which have not provided any data and may not even know of the existence of the MatchMaker! organization.

ENTER THE MATCHMAKER!

MatchMaker! is a relational database product, which we developed as a part of our group project. The program organizes and processes detailed materials flow information about specific facilities and generic industry types. Using input and output data for broadly defined material flows (e.g., solid, liquid, and gaseous items including steam and water), MatchMaker! is capable of generating reports that recommend potential symbiotic linkages between facilities.

MatchMaker! can suggest the kinds of pairings that are now orchestrated by waste exchange organizations. But while typical waste exchange organizations can only help match generators and end users that are actively seeking one another, MatchMaker! can create proactive matches between firms which have not provided any data and may not even know of the existence of the MatchMaker! organization. This sort of matching can help firms identify sites or geographic regions most amenable to waste linkages, and may provide critical insights for city or regional planners.

MatchMaker! is able to suggest potential matches between firms by drawing on generic flows organized by the standard industrial classification system (SIC) codes. If flow data are available for specific firms within the designated geographical search region, the program will identify such matches. If flow data are not available for firms within the region, the program will estimate probable flows based upon data gathered from firms in other regions belonging to the same SIC code, as well as generic profiles of flows for each SIC code.

By standardizing the names of all materials listed, MatchMaker! is able to automate the process of matching generators with end users. As all materials must be entered into the database according to a menu-driven taxonomy, there is no room for the inconsistent and sometimes ambiguous labeling of materials which plagues traditional waste exchange databases.

Using publicly available data sources (in our case, a $55 CDROM entitled ProCD Select Phone), MatchMaker! can extract the name, address, SIC code, and geo-referenced coordinates of most businesses in the United States. Because of the geo-referencing, searches for potential matches can be limited to a narrow geographic radius (appropriate for steam exchanges) or can be country-wide (appropriate for expensive electronic components). Eventually, MatchMaker!'s matching logic can be made to incorporate systems analysis optimization techniques.

The Development of MatchMaker!

Bechtel delivered to the group an Excel-based database of the Brownsville data. The spreadsheet structure was adequate for a trial of concept, which was proved in the Brownsville case. To move beyond the pilot phase a genuine relational database model was needed.

The relational database, if set up correctly, will substantially reduce the problem of inconsistent data. It also will allow the matching process to be done from within the database application. The application will be more stable and more easily maintained and the groundwork will be laid for the eventual migration to more powerful databases in the future.

First we designed the structure of the database, and then we created the database in Microsoft Access, a standard industry tool for the Windows PC. The new database features several design changes and greater functionality as compared to the original Excel model. These changes are described below.

New Features

The information about each firm or industry has been normalized – that is, broken up into separate tables. This new structure eliminates multiple entry of data, and makes for easier maintenance of the database.

Firms

Each firm has a master record, which contains such information as headquarters address, chief contact, and phone number.

Locations

For every firm, there can be number of locations, each of which has an SIC code, address, contact details and description.

Material Flows

The material flows were formerly contained in two tables, one for materials, and one for utilities. We could not find any specific reason for splitting the two flows and have therefore stored all material flows in one table. Thus, for each location, we can have any number of incoming and outgoing flows of materials or utilities (e.g. water, electricity, gas).

SIC Codes

Similarly, the database is now driven by Standard Industry Classification Codes. This system gives a consistent record of each location's true industry. Where the SIC code is obviously too broad, there is room to "zoom down" one more level and add discriminatory classification. This structure allows flows to be averaged on the basis of SIC code, generating standard generic flow data for each industry.

Material Codes

Similarly, the flows themselves required a classification system. This is crucial to the success of the database, because proper material flow matching is the goal of the program. Without a consistent material classification system, matching flows would be immensely difficult. The start of a predefined hierarchy has been incorporated into the database. Extension of the taxonomy given will be necessary as new information is added to the database.

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How it Fits Together

For each firm there are locations for which we have listed material flows. The locations are described by SIC codes, and the materials by our new material codes. Matching of flows and standardization of industry flows now becomes a reality.

How Information is Entered into MatchMaker!

When users open up the database, they are presented with the menu pictured below.

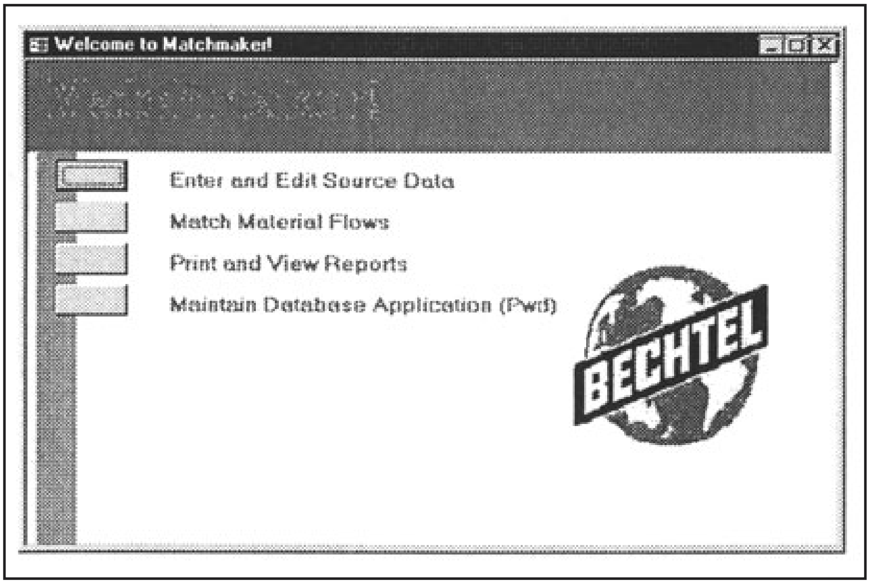


Figure 1 Database Front Page

The menu offers four options: editing data, printing reports, matching flows, and maintenance. Initially the add/edit data menu option will be the main one picked. A secondary menu (not shown) gives options for adding and editing data for Firms, SIC Codes, Material Flow Types, and any other data that need to be edited. Most of the effort in the early stages should be spent on the data input side. Hence most of the development work has been done in that area.

If users press the button next to Edit Firms, they will be presented with the combination Firms/Locations form below.

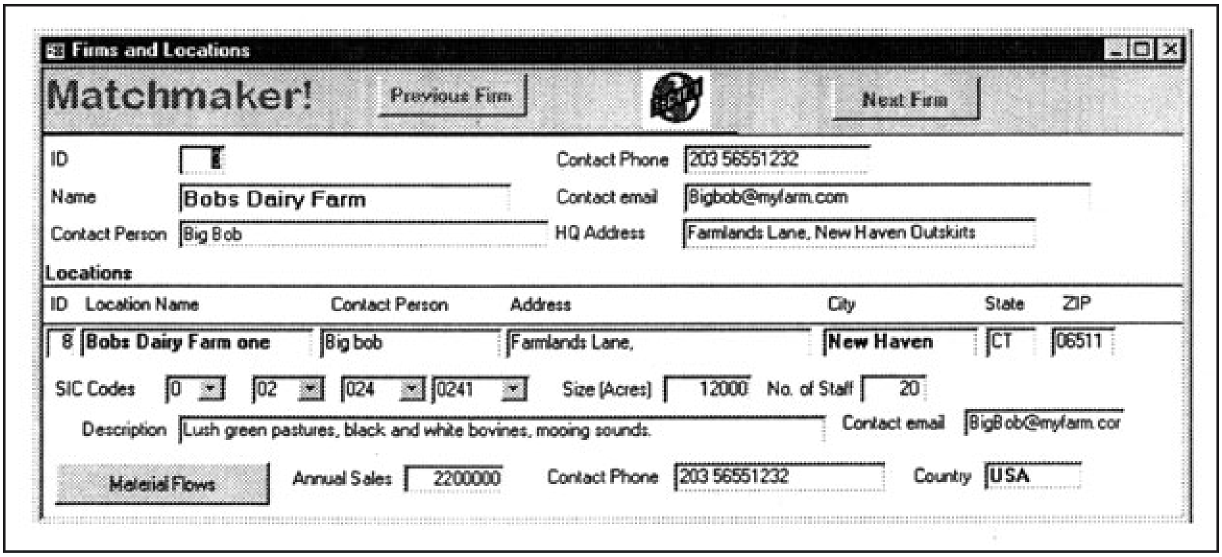


Figure 2 Firms/Locations Screen

The top of the form, with the white background, feeds data into the Firms table. The data here are very basic, reflecting a design philosophy to capture only the most relevant information and not to crowd out the users with data of lesser value.

The shaded (actually yellow) area shows one location. Additional locations can be added simply by moving the cursor down. The information captured here is a little more detailed and includes the four levels of SIC code, indicators of size (Staff and Area) and contact details. Longitude and latitude data are also stored but are not on the form as they are generally not known at the point of data entry. Commercial programs exist to convert address information into so-called geocodes.

When clicked, the SIC code fields show the complete list of relevant numeric and definitional information. The user can either type in the code or scroll down the list to the correct code. Additionally, typing in the first digits will scroll the list to the appropriate point.

When the Location data are complete, the user clicks on the "Material Flows" button. A new form pops up, as presented below.

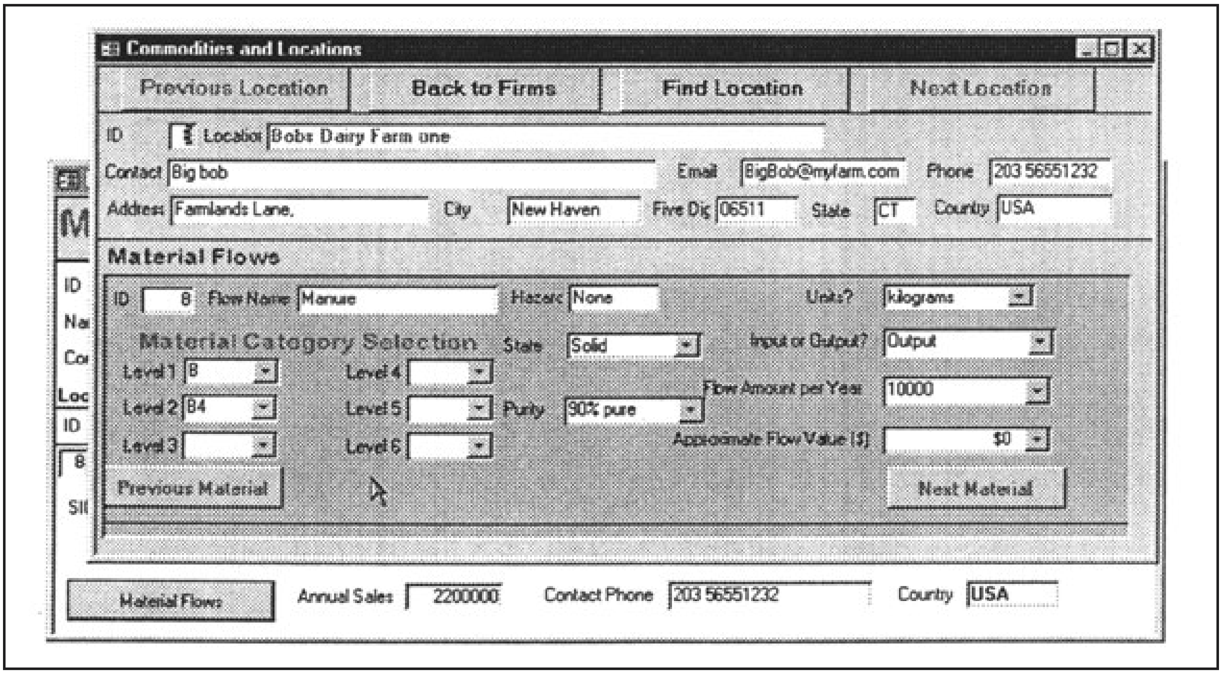


Figure 3 Material Flows Screen

For each location, there can be any number of flows of any type. The flows are added sequentially, and can be viewed by pressing the "Next Material" and "Previous Material" buttons. The top half of the form is data fed in from the previous form. The lower half of the form shows one material flow at a time. Basic information such as hazard code, flow volume and units, direction of flow (i.e., input or output), purity, and phase (state) is entered from drop down lists.

Material and Utility Taxonomy

The free-form field for "Flow Name" is not used for matching, which instead is done using the "Material Category Selection" level drop-down lists. Like the SIC code entry, the user can either select from the list, type in the value, or a combination of both.

These taxonomy lists are crucial for proper matching and thus are the keystones of the project. The function of the taxonomy is two-fold:

- provide a range specificity
- improve matching efficacy

An extensive hierarchy will provide the user with a continuum from general to highly specific. If one is searching for a well characterized item (e.g. aluminosilicate glass), then the search engine will find flows that match only that particular item (i.e., borosilicate and soda-lime glass will not be matched).

However, if any of a class of items will do (e.g., hydrocarbon solvents), then MatchMaker! will find a vast array of items which are listed under the category of hydrocarbon solvents (i.e., alcohols, acetates, hexanes, etc. will be found). Since the program graphically presents the hierarchy via drop menus, the user may decide that a more general selection is appropriate and choose not to use the lower levels. MatchMaker! will only find matches when reports matching the more generic criteria are generated. In this case, the possibility of successful matching is increased.

The fact that the taxonomy is pre-established also will increase the probability of successful matching. By selecting the search element from a list, near-misses due to misspelling, alternate naming schemes (e.g., butanol and butyl alcohol), misordering of phrases (e.g., "rubber, natural" as opposed to "natural rubber"), and formatting errors (e.g., extra spacing, misplaced punctuation) are prevented.

Associated with the advantages of a pre-established hierarchy are the problems of rigidity in a dynamic system. Depending on the use and contents of the database, the user may wish to expand the hierarchy to include new items or eliminate bulky, unused portions of the list. MatchMaker! has been designed with this function in mind. The hierarchy editing form is accessed from the add/edit menu form and will allow the user to perform modifications, additions, and deletions. All matches that follow will reflect the changes. The database stores the material code, not the material name in each flow, so if the material name is altered (e.g., the spelling of butanol) it will not affect the matchmaking ability.

Associated with the advantages of a pre-established hierarchy are the problems of rigidity in a dynamic system. Depending on the use and contents of the database, the user may wish to expand the hierarchy to include new items or eliminate bulky, unused portions of the list. MatchMaker! has been designed with this function in mind.

In order to properly design our hierarchy, we performed an extensive World Wide Web search of material exchange bulletin boards. What we found was a great disparity of taxonomies; the results offered us little help in selecting a standard. Instead, we selected a range of popular elements from numerous well-designed sites and then condensed and tailored them to suit our needs. Then, using a broader set of Web hierarchies, we flushed out the top two tiers to a modest but by no means exhaustive extent. In hopes of better demonstrating the function and structure of our model, we also performed a similar process on several elements in the Chemicals, WORP (waxes, oils, rubbers, plastics), and Metals/Sludges categories. The classification scheme as presented in Appendix B is incomplete but provides a useful prototype for hierarchic design.

Mass Regional Data

Data can be imported from available CD databases of U.S. industries such as "Select Phone" from ProCD. These databases contain information available in the Yellow pages for every region in the U.S. The Yellow pages classifications are used to generate one or more SIC Codes for each location. The locations are also geo-coded with longitude and latitude coordinates for each. Essentially, the CDs contain all of the data on the firm level and most of the data on the location level. Material flow data are not commercially available on CD.

Basic Matching

After these steps are taken, the MatchMaker! database can perform matching of material flows. The user has the choice of a number of reports. These reports vary by grouping and by material level. A company that was looking for a basic solvent of any type would run a "Flow by Material Type – Material Level 2" report. This report would show all of the input and output flows of that material. A company wanting to look at all of its specific matches would run "Match Flows by Company – Level 5" which would list all matches for that company's inputs and outputs.

The Level of Current Development

The fundamental structure of MatchMaker! is in place. Critically, this includes the underlying table design and associated queries. Forms for entry of Firm, Location, and Flow data have been created (as were shown above). The master matching queries and reports have been created for each method of grouping and one level. It is a relatively trivial matter to create new feeder queries to make reports that match materials on different levels.

A menu system is in place that can be progressively added to as the number of reports and forms expands. Simple forms for editing SIC Codes and Material Categories either exist or are easy to create. However, with data of this nature, it is simple to edit directly in the table.

Industry data were imported from "Select Phone" CD for the New Haven area, and are stored in a table. Additional data for larger or different areas are easy to import from this or similar products.

The Next Steps

Currently, there is only sample flow data in the MatchMaker! system. The Brownsville and Saudi data need to be imported – a task which we did not undertake since the specific material flows need to be collected and coded using the new material classification system.

Basic matches will be performed by running the appropriate reports. To limit the size of reports, a simple filter system needs to be incorporated so that users can show only those flows or companies in which they are interested. Because of the current paucity of data, this function is not yet necessary.

There are several cosmetic and "nice to have" features that take a long time to create but should eventually be added. These include a tree structure for adding the material and SIC codes, database security, database maintenance (such as repairing and compressing), and simple ad-hoc reporting and querying.

User Testing

User testing will certainly reveal areas that require improvement. Currently the database needs to be maintained by a person proficient with the Access product. Bechtel Research and Development may wish to extend and further develop the product.

MatchMaker! – The True Power

When enough data have been entered into the system, and a critical mass of standard SIC code-based material flows is available, then the true power of MatchMaker! will be revealed. In a relatively simple yet computationally intensive procedure, the SIC codes from the phone book CD-ROM are matched against the standard flow data. An overall flow schema of the area in question is generated and can be analyzed in several ways. First, the quantity of excess input and output flows from the entire region can be studied. For example, Connecticut would show a large inflow of oil and petroleum. If the database also showed an unusually large inflow of aluminum extrusions, or paper products, then perhaps there would be an opportunity.

The Flow Magnitude

The next level of analysis does not look at the difference of inflows and outflows, but rather the magnitude of flows. If there are noticeably large flows inside the region, then attention can be focused on determining whether they are being routed to the appropriate companies. For example, if there are a lot of wood input and output streams from local industries, we should investigate whether the wood is flowing entirely within the local economy or whether the net flows are actually imports and exports away from the area.

Further refinement will produce a report that gives distance-weighted flows, which will lower the ranking of very small flows that happen to be next door compared to very large flows down the street. This feature is particularly relevant to common commodities such as steam, water, electricity, and sludge.

Proximity

At later stages, when more data are entered, proximity of data flows can be calculated by using an equation to calculate the distance between the two geo-coded points. This distance equation has been programmed into MatchMaker! already and is available to use for calculated fields on reports. This feature will allow reports to be generated that show matching flows by proximity to the company in question. Further refinement will produce a report that gives distance-weighted flows, which will lower the ranking of very small flows that happen to be next door compared to very large flows down the street. This feature is particularly relevant to common commodities such as steam, water, electricity, and sludge.

Optimizing

Finally, the distance, flow, and material type data can all be exported into a systems optimizer application. This optimizer may be able to match flows across a larger area, such as New Haven County, and will optimize for the correct sequence and matching of flows. This step is an area where Bechtel can add a lot of value since they have developed proprietary optimization tools for use in other business sectors.

The choice of Microsoft Access as the database tool was made because this application allows for easy migration to more powerful databases. As an intermediate step, the tables of data can be migrated to a server database, such as Oracle, Sybase, or SQL Server. The front-end screens, forms, and reports would be retained. This simple migration is very easy to achieve. The next step is to change the existing queries to queries in native SQL, which can be directly passed through to the back end database. This improvement will significantly speed up searches and matches using very large amounts of data.

Finally, the forms and reports can be migrated to an industrial strength program such as Powerbuilder or Oracle Reports. This task requires a MIS project, with significantly more resources and scale than the MS Access solution. This final step, which should include web publishing, may not even be required as MS Access gains more robustness and high-end features with each new version.

MatchMaker! was developed in Access 97, the most recent version of MS Access available at the time of our project. Unfortunately this is not backwardly compatible with previous versions. However, if a ‘developer kit’ is purchased for a few hundred dollars, a “run time” version of Access 97 can be distributed with the MatchMaker! application. This would allow, for example, multiple data entry users using the runtime Access and one or two master users with the full product. Users of the runtime version would not be able to alter the structure of the MatchMaker! program, but could edit data, perform matches, and print reports as demonstrated before.

As the database grows, it would be tempting to copy it to allow different users to enter data at once. This is not ideal. If the users are all in the same office, they can log on to the database at the same time. However, if the users are separated by a greater distance, and are not networked, then splitting the database may be the only solution. In this case, for the data entry phase, an empty database would be provided to the satellite data entry group, and when the data entry was finished, the new records would simply be appended to the master database. Indexing concerns here require a unique reference “key” field in each table, so the satellite database would need to have tables which assign keys from a different start point.

However, the best medium term solution is to use the web publishing properties of Microsoft Access and place the database on an intranet, or the Internet. This would allow multiple updating of the same data tables at once. This new feature of Access has not been tested by the group, and would require some exploration before adoption.

The Far Future

When the SIC code data are sufficient to perform rough matches on a regional scale, the sheer volume of information presented will be overwhelming. One way to represent this array of information is on a map. The matched flows could be shown by drawing lines from the start to finish points, with the thickness of the line representing flow rate, and the color or line style representing flow type. The tools to do this are commercially available. With some development, MatchMaker! would be able to export a flow line file to a mapping program such as “Maptitude” which can plot the flow lines onto a standard area map. The team has been experimenting with this technology with some success.

When the SIC code data are sufficient to perform rough matches on a regional scale, the sheer volume of information presented will be overwhelming. One way to represent this array of information is on a map.

THE BIG QUESTION MARK: OWNERSHIP AND DATA COLLECTION

As it currently stands, MatchMaker! is a database frame without data. The tool works, but it is useless without input and output flow information for specific firms and SIC codes. Data collection will be an expensive endeavor, involving surveys, site visits, database mining, and literature review. While we have developed the basic framework of the MatchMaker! tool, we have not resolved the issue of ownership and funding for data collection.

We have envisioned three possible scenarios for the future control of MatchMaker!, each with advantages and disadvantages.

Scenario #1: Private Ownership

Under this scenario, a private organization such as Bechtel would maintain control of the database. Some of the initial data collection activities could be funded by client organizations interested in immediate local matchmaking similar to the Brownsville, Texas project. Additional data collection costs would be absorbed as research and development expenses toward a future product offering. As an inducement for early cooperation in providing input and output flow information, the owner of the database might offer free or discounted matchmaking services to participating firms in key industries.

From a utilitarian perspective, the primary drawback to this ownership scenario is that some potential clients would be unable to afford the prices charged for the matchmaking service.

In the short-run, we propose that MatchMaker! remain in the stewardship of the Yale School of Forestry and Environmental Studies. Student researchers should continue to develop the taxonomy of materials and collect flow data for firms in the greater New Haven metropolitan area.

Scenario #2: Public Ownership

Under this scenario, the federal government would own and operate the database. Firms could be required to submit input and output flow data, or alternatively, firms could be offered tax breaks and regulatory relief in exchange for their cooperation. While this scenario would provide broader access to the data than would the private ownership scenario, firms might be leery of participating and be hesitant to provide accurate flow data to a regulatory authority.

Scenario #3: Non-profit Ownership

Under this scenario, MatchMaker! would be controlled by a non-profit organization such as Yale University or the Environmental Defense Fund. Funding could come from a variety of sources including government grants, sliding scale subscriptions, or user fees based upon cost savings achieved.

In the short-run, we propose that MatchMaker! remain in the stewardship of the Yale School of Forestry and Environmental Studies. Student researchers should continue to develop the taxonomy of materials and collect flow data for firms in the greater New Haven metropolitan area.

Many critics question the economic viability of materials exchanges and pose the question: “Aren’t we talking about low-value commodities? If there were really significant cost savings opportunities, wouldn't businesses already have identified them?" In response, we offer the observation universally shared by the organizers of the waste exchanges with whom we spoke. Millions of dollars are saved each year by generators and users that find each other through waste exchange organizations. Some of the benefits are due to the decreased costs of industrial feedstocks, while other benefits stem from averted disposal expenditures. There appears to be plenty of low-lying fruit still out there. Adding sophistication, power, and detail to the matchmaking process would only increase cost savings.

APPENDIX A Sample web pages from on-line waste exchanges

Recycler's World - Information & Material Exchange Directory

Recycler's World

[Go to Main Menu | Add Your Exchange]

Information & Material Exchange Directory

Industrial Services of America

- Alabama Waste Materials Exchange (ALME)
- Alaska Materials Exchange
- Alberta Waste Materials Exchange
- Arizona Waste Exchange
- Arkansas Industrial Development Council
- BARTER Waste Exchange
- BBMS - La Bourse Bahillard des Matières Secondaires
- British Columbia Waste Materials Exchange
- By - Products & Waste Search Service
- C.R.U.M.B. - Crumb Rubber Universal Marketing Bureau
- CALMAX - California Material Exchange
- California Waste Exchange (CWE)
- Canadian Chemical Exchange
- Canadian Waste Materials Exchange
- Chicago Board of Trade
- Comex - Commodity Exchange Inc.
- ConnTAP Materials Exchange
- Cotton Commodity Exchanges
- Durham Region Waste Exchange
- Essex-Windsor Waste Exchange
- European Plastics Converters
- Florida Recycling Material System (FRMS)
- Gems, Rocks & Minerals Exchange
- Great Lakes Waste Exchange
- HIMEX-Hawaii Materials Exchange
- Hudson Valley Materials Exchange
- I.M.E.X. - Industrial Materials Exchange
- Indiana Materials Exchange
- Industrial Material Exchange Service
- Industrial Waste Information Exchange
- Inter-Continental Glass Exchange
- Inter-Continental Metal Exchange
- Inter-Continental Paper Exchange
- Inter-Continental Rubber Exchange
- Inter-Continental Tire Exchange
- Inter-Continental Wood Exchange
- Intercontinental Waste Exchange (IWE)

LUBE

SEC MAT

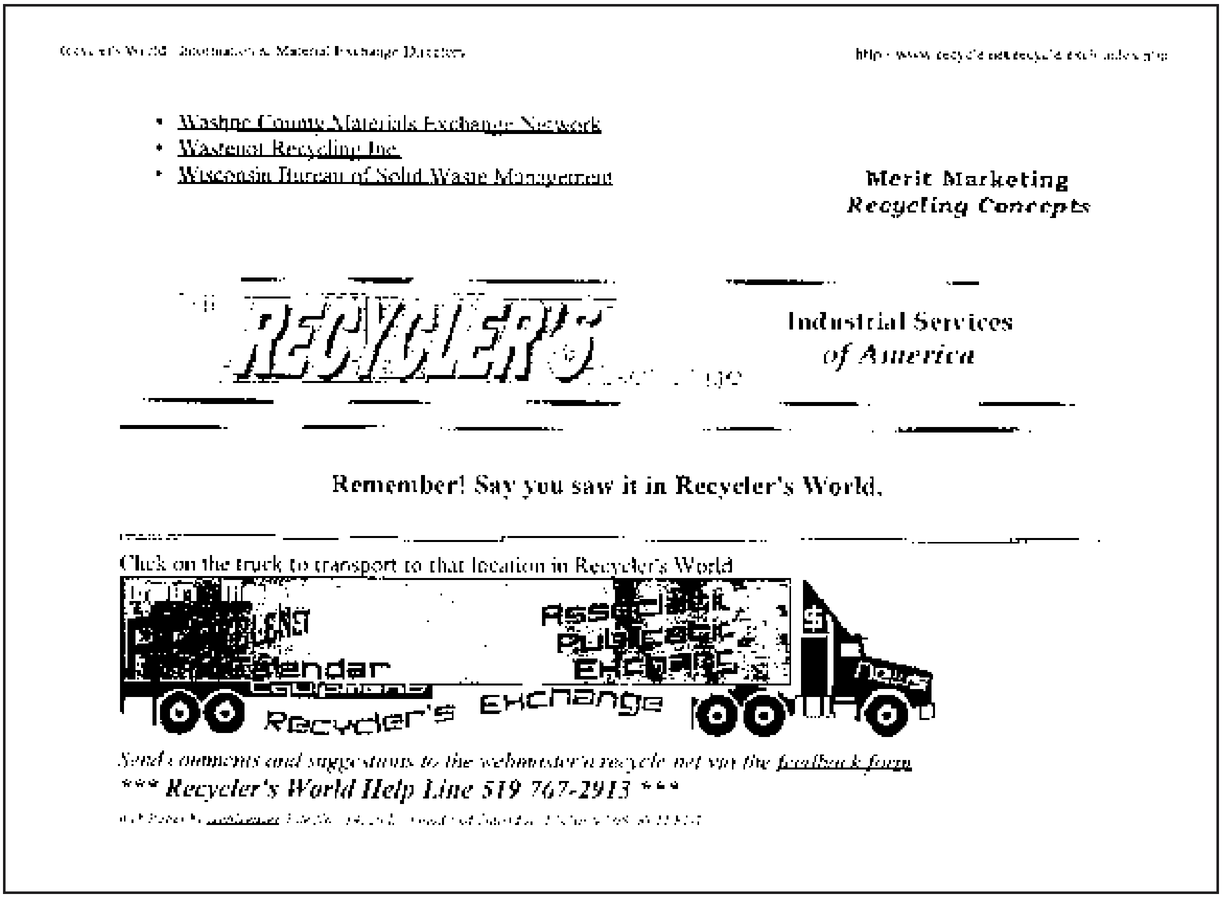
more than 40 years of experience in plastic recycling & washing plants

Rubber Broker's of Canada

PARMA VINYL Because Vinyl is Recyclable

1 of 3

- International Fiberglass Exchange
- International Resource Recovery Network
- Kansas Materials Exchange
- Kentucky Industrial Materials Exchange
- Kobe Rubber Exchange
- Kuala Lumpur Commodity Exchange (KLCE)
- LME - London Metal Exchange
- La Bourse Quebecoise Des Materiers Secondaires
- Louisiana/Gulf Coast Waste Exchange
- MISSTAP
- Manitoba Waste Exchange (MBWE)
- Mat-Ex - Upstate New York Materials Exchange Program
- Michigan Resources Exchange Services
- Minnesota Technical Assistance Program
- Missouri Environmental Improvement Authority
- Money Lynx
- Montana Industrial Waste Exchange
- National Materials Exchange Network
- Nebraska Materials Exchange Program
- New Hampshire Waste Exchange (WasteCap)
- New Jersey Industrial Waste Information Exchange
- New Mexico Material Exchange
- Northeast Industrial Waste Exchange
- Ohio WasteNet - CEC Consultants
- Oklahoma Waste Exchange Program
- Ontario Waste Materials Exchange
- Pacific Materials Exchange
- Peel Regional Waste Exchange
- Portland Chemical Consortium
- Puerto Rico Waste Exchange
- Quebec Materials Waste Exchange (QMWE)
- Recycler's Exchange
- Resource Exchange Network for Eliminating Waste (RENEW)
- Rivanna Solid Waste Authority Exchange Program
- Rocky Mountain Materials Exchange
- SEMREX-Southeastern Minnesota Recyclers Exchange
- Saskatchewan Waste Materials Exchange (SWME)
- Singapore Commodity Exchange Ltd.
- South Carolina Waste Exchange
- Southeast Waste Exchange
- Southern Waste Info Exchange
- Southwest Virginia CommoditiesTrader
- Surplus Exchange
- TEE - Textile FiberSpace Exchange
- Tennessee Materials Exchange
- Tokyo Commodity Exchange (TCE)
- Transcontinental Materials Exchange
- Universal Plastics Exchange
- Vermont Business Materials Exchange
- WASTELINK - Div. of Tencon Inc.


• Washoe County Materials Exchange Network
• Wastenot Recycling Inc
• Wisconsin Bureau of Solid Waste Management
Merit Marketing
Recycling Concepts
RECYCLER'S
Industrial Services
of America
Remember! Say you saw it in Recycler's World.
Click on the truck to transport to that location in Recycler's World
Calendar
Recycler's Exchange
Send comments and suggestions to the webmaster via the feedback form
*** Recycler's World Help Line 519 767-2913 ***

1997 March - April IMEX Catalog http://www.metrokc.gov/hazwaste/imex/toc.html

Local Hazardous Waste Management Program In King County

IMEX Catalog Table of Contents

Last Updated: April 16, 1997
Please e-mail IMEX directly at: imex@metrokc.gov

- *Search the King County home page, including IMEX*
- *On-line Listing Form* *Add your wanted or available materials to the IMEX catalog.*
- *Deadlines for IMEX Listings* *Due dates for getting your listings in specific catalog issues*
- *IMEX Report*
- *Business Waste Line*
- *How to Use This Catalog*
- *Laboratory Chemicals (Special Instructions)*
- *Telephone and address list of other material exchange & recycling networks*
- *Material exchange and recycling networks on the 'net*
- *Assistance for Your Waste Problems*

Available

*New Listings are marked with an asterisk (*), example: *A11092818*

01 Acids	02 Alkalis	03 Other Inorganic Chemicals	04 Solvents
05 Other Organic Chemicals	06 Oils/Waxes	07 Plastics/Rubber	08 Textiles/Leather
09 Wood/Paper	10 Metals/Metal Sludges	11 Miscellaneous	12 Laboratory Chemicals
13 Industrial/Other Equipment			

Wanted

1 of 2 4/24/97 7:36 PM

The Southern Waste Information Exchange (SWIX)

A Service of Keep Florida Beautiful, Inc.

KEEP FLORIDA *Beautiful*

MATERIALS AVAILABLE

How to respond to or place a Material Available listing

* = New Listing

I. Acids

Code Number	Material	Quantity/Year	Location
SW:A01-0510	Chromic Acid	3,300 gallons, one time	AL
SW:A01-0512	Hydrochloric Acid	12,000,000 gallons	TX
SW:A01-0598	Hydrochloric Acid	16,000,000 gallons	FL
SW·A01-0612	Hydrochloric Acid	400,000 pounds/year	FL
SW:A01-0613	Solidified Pyrophosphoric Acid	4,400 pounds	GA

II. Alkalis

Code Number	Material	Quantity/Year	Location
SW A02-0611	Calcium Carbonate Lime Mud	13,000 tons/year	GA
SW·A02-0601	HCE Black Liquor	100,000 pounds/day	FL
SW·A02-0587	Hydrated Lime	3 tons per week	FL
SW:A02-0624*	Hydrogen Peroxide	55 gallons	FL
SW·A02-0618	Lime Mud	270,000 cubic yards	FL
SW:A02-0620	Lime Solid	375,000 tons	FL

III. Other Inorganic Chemicals

Code Number	Material	Quantity/Year	Location
SW:A03-0530	Amorphous Silica	High tonnage	FL
SW A03-0614	Iron Sulfate	50,000 pounds/week	MS

1997 March - April IMEX Catalog   http://www.metrokc.gov/[illegible]

*New Listings are marked with an asterisk (*), example: *W11092818*

01 Acids	02 Alkalis	03 Other Inorganic Chemicals	04 Solvents
05 Other Organic Chemicals	06 Oils/Waxes	07 Plastics/Rubber	08 Textiles/Leather
09 Wood/Paper	10 Metals/Metal Sludges	11 Miscellaneous	12 Laboratory Chemicals
13 Industrial/Other Equipment			

Volume 9 Issue No. 2
Return to the CESQG Home Page

Keeper of the CESQG Network Pages
Local Hazardous Waste Management Program in King County
King County Department of Natural Resources (formerly Metro)
Hazardous Waste Unit
130 Nickerson St., Suite 100
Seattle, WA 98109-1658
email: kcecsqg@metrokc.gov
Phone: (206)689-3051

```
Established :    1/13/96
Last update :    4/17/97
```

SWIX: Materials Available http://www.webvista.com/swix-ma.html

IV. Solvents

Code Number	Material	Quantity/Year	Location
No listings at this time			

V. Other Organic Chemicals

Code Number	Material	Quantity/Year	Location
SW:A05-0617	Diethylene Triamine (DETA)	15,000 pounds	AL
SW:A05-0599	Ethylene Glycol/Antifreeze/Coolant	NA	UT
SW:A05-0545	Glycerine	3,000 gallons	FL
SW:A05-0445	Heat Transfer Fluids - Including Glycols	Various amounts	AR

VI. Oils and Waxes

Code Number	Material	Quantity/Year	Location
SW:A06-0625*	Used Oil/Fuel Mixed	12,000 gallons	FL
SW:A06-0517	Waste Motor Oil	2,750 gallons	TN

VII. Plastics and Rubber

Code Number	Material	Quantity/Year	Location
SW:A07-0628*	Amoco TA/22 Resin	84,000,000 pounds	SC
SW:A07-0544	Crumb Rubber	6,000,000 pounds	FL
SW:A07-0542	Microfilm Tape	Various Amounts	FL
SW:A07-0560	Nylon/Rubber Tires	Varies	FL
SW:A07-0549	Polyvinylchloride Foam	120,000 pounds	TN
SW:A07-0623*	PP & PE Blend	480,000 pounds	MO
SW:A07-0543	Processed Tire Buffings	2,016,000 pounds	FL
SW:A07-0602	TDI Foam	50,000 pounds	FL
SW:A07-0514	Teflon	100,000 pounds	AR
SW:A07-0483	Vinyl Nitrile Foam Scrap	6 truckloads per month	FL
SW:A07-0621*	Waste Ink Buckets - HDPE #2	78,000 pounds	KY

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APPENDIX B Prototype materials taxonomy

CATEGORY LEVEL A: CHEMICALS

A1 Acids
- A1A inorganic
  - A1A1 hydrogen sulfide
  - A1A2 hydrogen cyanide
  - A1A3 hydrofluoric acid
  - A1A4 hydrochloric acid
- A1B organic

A2 Alkali
- A2A inorganic
  - A2A1 ammonia
  - A2A2 sodium hydroxide
- A2B organic

A3 Solvents
- A3A inorganic
- A3B organic
  - A3B1 hydrocarbons
    - A3B1A 1,2-epoxybutane
    - A3B1B 1,2-butadiene
    - A3B1C 2,2,4-trimethylpentane
    - A3B1D acetalhehyde
    - A3B1E acetates
      - A3B1E1 n-butyl acetates
      - A3B1E2 methyl ether acetate
      - A3B1E3 isopropyl acetate
      - A3B1E4 ethylene glycol diacetate
    - A3B1F acetone
    - A3B1G acetophenone
    - A3B1H alcohols
      - A3B1H1 isopropranol (isopropyl alcohol)
      - A3B1H2 methanol (methyl alcohol)
      - A3B1H3 n-butanol (n-butyl alcohol)
      - A3B1H4 propanol (propyl alcohol)
      - A3B1H5 octanol (octyl alcohol)
      - A3B1H6 methyl oxitol
    - A3B1J benzene
    - A3B1K biphenyl
    - A3B1L dibenzofuran
    - A3B1M ethyl glycol
    - A3B1N ethylbenzene
    - A3B1P ethylene glycol monomethyl ether
    - A3B1Q hexanes
    - A3B1R hexylene glycol
    - A3B1S methyl ethyl ketone (MEK)
    - A3B1T methyl-t-butyl ether
    - A3B1U napthalene
    - A3B1V phthalates
      - A3B1V1 di-2-ethyl-,hexylphthalate
      - A3B1V2 dioctyl phthalate
      - A3B1V3 bis(2-ethylhexyl) phthalate
    - A3B1W propylene glycol monomethyl ether
    - A3B1X propylene oxide
    - A3B1Y xylenes

A3B2 N-containing compounds
- A3B2A 2,4-dinitrotoluene
- A3B2B 2-nitropropane
- A3B2C 4-nitrobiphenyl
- A3B2D 4-nitrophenol
- A3B2E acrylamide
- A3B2F acrylnitrile
- A3B2G diazomethane
- A3B2H hydrazine (35%)
- A3B2J hydroxylamine hydrochloride
- A3B2K nitrobenzene
- A3B2L nitromethane
- A3B2M triethylamine

A3B3 P-containing compounds
- A3B3A phosgene
- A3B3B phosphine

A3B4 mixed compounds
- A3B4A bromoform
- A3B4B bromomethane (methyl bromide)
- A3B4C carbon tretrachloride
- A3B4D chlorobenzene
- A3B4E chloroethane
- A3B4F chloroform
- A3B4G chloromethane (methyl chloride)
- A3B4H 1,4-dichlorobenzene
- A3B4J freons
  - A3B4J1 freon-113
- A3B4K halons
  - A3B4K1 halon-1301
  - A3B4K2 halon-1211
- A3B4L perchloroethylene
- A3B4M perchloroethylene
- A3B4N trichlorobenzene
- A3B4P trichloroethane
- A3B4Q trichloroethylene
- A3B4R vinyl bromide
- A3B4S vinyl chloride
- A3B4T 1,1,2,2-tetrachloroethane
- A3B4U 2,4,5-trichlorophenol

A3B5 halogen-containing compounds
- A3B5A 2-acetylaminofluorine

A4 Salts

A4A inorganic
- A4A1 calcium hypochlorite
- A4A2 calcium oxide
- A4A3 magnesium oxide
- A4A4 potassium dichromate
- A4A5 potassium ferricyanide
- A4A6 sodium chloride

A4B organic
- A4B1 sodium acetate, anhydrous
- A4B2 sodium proprionate

A5 Ceramics
- A5A oxide
  - A5A1 yttria
  - A5A2 magnesia
  - A5A3 alumina
- A5B non-oxide
  - A5B1 boron carbide
  - A5B2 silicon nitride
  - A5B3 silicon carbide
- A5C silicate
  - A5C1 glass
    - A5C1A silica
    - A5C1B soda-lime
    - A5C1C borosilicate
    - A5C1D aluminosilicate
    - A5C1E leaded
  - A5C2 cement
  - A5C3 pottery and structural clay

A6 Non-Solid Petroleum Distillates
- A6A methane
- A6B ethane
- A6C propane
- A6D butane
- A6E naptha
- A6F kerosene
- A6G gas oil

A7 He, H2, X2 gases
- A7A chlorine
- A7B cyanide
- A7C fluorine
- A7D helium
- A7E hydrogen

A8 Inorganic Solids
- A8A carbon
  - A8A1 carbon, black
  - A8A2 carbon, charcoal
- A8B silica (silicon dioxide)

CATEGORY LEVEL B: AG./FOOD

B1 Compost

B2 Fish Wastes

B3 Fruit and Vegetable Wastes

B4 Manure

B5 Mulch

B6 Rendering and Protein Wastes

B7 Processed/Packaged Food Wastes

B8 Fly Ash

CATEGORY LEVEL C: WORP

C1 Wax
- C1A petrolatum

C2 Oil
- C2A lube oil

C3 Rubber
- C3A natural
- C3B synthetic
  - C3B1 butyl
  - C3B2 EPDM
  - C3B3 fluorocarbon
  - C3B4 latex
  - C3B5 neoprene
  - C3B6 nitrile
  - C3B7 polybutadiene
  - C3B8 silicone
  - C3B9 SBR

C4 Plastic
- C4A ABS
- C4B EP
- C4C nylon (polyamide)
- C4D PBT
- C4E PET
- C4F polycarbonate
- C4G polyethylene
- C4H polypropylene
- C4I PS
- C4J PVC
- C4K SAN
- C4L SI
- C4M teflon
- C4N vinyl nitrile
- C4P unidentified plastic scraps
  - C4P1 film scrap
  - C4P2 shrink wrap
  - C4P3 stretch wrap
  - C4P4 packaging peanuts
  - C4P5 plastic bags

CATEGORY LEVEL D: TEXTILES/LEATHER

D1 Cotton

D2 Wool

D3 Burlap, Jute, Sisal

D4 Polyurethane Foam

D5 Polyester Fibers

D6 Nylon Fibers

D7 Other Syntheic Fibers

D8 Rags and Wipers

D9 Leather

CATEGORY LEVEL E: WOOD/PAPER

E1 Pallet Reels and Crates

E2 Lumber (Virgin or Reusable)

E3 Waste Wood

E4 Wood Chips, Shavings, and Sawdust

E5 Paper (Virgin or Reusable)

E6 Loose Paper Waste

E7 Baled Paper Waste

E8 Paperboard

E9 Corrugated Cardboard

CATEGORY LEVEL F: METALS/SLUDGE

F1 Iron and Steel
- F1A used/reusable iron
- F1B scrap iron
- F1C ship breaking and railroad iron
- F1D used/reusable steel
- F1E scrap steel

F2 Non-Ferrous Metals
- F2A aluminum
- F2B brass and bronze
- F2C copper
- F2D lead
- F2E magnesium
- F2F tin
- F2G zinc
- F2H other non-ferrous metals

F3 Exotic Metals
- F3A cobalt
- F3B nickel
- F3C mercury
- F3D titanium
- F3E tungsten
- F3F other exotic metals

F4 Precious Metals
- F4A gold
- F4B palladium
- F4C platinum
- F4E silver
- F4F other precious metals

APPENDIX C Sample MatchMaker! reports.

MATCH FLOWS BY FIRM AND LOCATION

Bobs Dairy Farm

Matches For Location: Bobs Dairy Farm one New Haven

Output

Matches for Material: Manure
Quantity of Flow: 10000 kilograms **Purity:** 03
Internal Name Manure

Firm Name Yale University **Location** Yale University Dining Services Food and other products recycler
Contact Person Bill Taco

Flow Type: Input **Flow Name:** "Food Stuffs" **Quantity:** 1000000 kilograms
Form: Solid **Purity:** 100% Pure

Firm Name Hamden Golf Course **Location** Hamden golf Course Public golf course
Contact Person Arnie Palmer

Flow Type: Input **Flow Name:** Manure **Quantity:** 1000 kilograms
Form: Solid **Purity:** 95% pure

Bobs Dairy Farm

Matches For Location: Bobs Dairy Farm one New Haven

Firm Name United Illuminating **Location** UI Fuel Cell Proj Pilot project - takes manure, makes methane, runs fuel cells. Innovative but smelly.
Contact Person Alva Edison

Flow Type: Input **Flow Name:** Manure **Quantity:** 1000 kilograms
Form: Solid **Purity:** 95% pure

Brick Manufacturer

Matches For Location: **Potential Brick Manufacturer** New Haven

Output

Matches for Material: Construction Material

Quantity of Flow: 10000 kilograms **Purity:** 03

Internal Name Brick bits

Firm Name Dodgy Brothers Construct **Location** Dodgy Brothers Construction Engineers and builders to the public.

Contact Person Dodgy Dan

Flow Type: Input **Flow Name:** Brick pieces **Quantity:** 10000 kilograms

Form: Solid **Purity:** Contaminated

Input

Matches for Material: Fly Ash

Quantity of Flow: 10000 kilograms **Purity:** 07

Internal Name fly ash

Brick Manufacturer

Matches For Location: **Potential Brick Manufacturer** New Haven

Firm Name Yale University **Location** Yale University Power Power Generation

Contact Person Bob Wildman

Flow Type: Output **Flow Name:** Fly ash **Quantity:** 10000 kilograms

Form: Solid **Purity:** 95% pure

Firm Name Connecticut Light and Po **Location** New Haven Coal Power Power generation

Contact Person

Flow Type: Output **Flow Name:** Flyash **Quantity:** 1038800 metric tonnes

Form: Solid **Purity:** Contaminated

Connecticut Light and Power

Matches For Location: **New Haven Coal Power** New Haven

Output

Matches for Material: Fly Ash

Quantity of Flow: 1000000 metric to **Purity:** 04

Internal Name Flyash

Firm Name Brick Manufacturer **Location** Potential Brick Manufacturer Typical Brick Manufacturer. Average of 5 sample companies

Contact Person

Flow Type: Input **Flow Name:** fly ash **Quantity:** 10000 kilograms

Form: Solid **Purity:** 90% pure

APPENDIX C, continued Sample MatchMaker! reports.

Output

Matches for Material: Construction Material
Quantity of Flow: 10000 kilograms **Purity:** 03
Internal Name Brick bits

[illegible]
Location: Potential Brick Manufacturer New Haven

Firm Name Dodgy Brothers Constru: **Location** Dodgy Brothers Construction Engineers and builders to the public
Contact Person Dodgy Dan

Flow Type: Input **Flow Name:** Brick pieces **Quantity:** 10000 kilograms
Form: Solid **Purity:** Contaminated

Dodgy Brothers Construction
Location: Dodgy Brothers Construction New Haven

Firm Name Brick Manufacturer **Location** Potential Brick Manufacturer Typical Brick Manufacturer Average of 5 sample companies
Contact Person

Flow Type: Output **Flow Name:** Brick bits **Quantity:** 10000 kilograms
Form: Solid **Purity:** 90% pure

Output

Matches for Material: Fly Ash
Quantity of Flow: 10000 kilograms **Purity:** 02
Internal Name Fly ash

Yale University
Location: Yale University Power New Haven

Firm Name Brick Manufacturer **Location** Potential Brick Manufacturer Typical Brick Manufacturer Average of 5 sample companies
Contact Person

Flow Type: Input **Flow Name:** fly ash **Quantity:** 10000 kilograms
Form: Solid **Purity:** 90% pure

Input

Matches for Material: Fly Ash

Quantity of Flow: 10000 kilograms **Purity:** 03

Internal Name fly ash

Brick Manufacturer

Location: Potential Brick Manufacturer New Haven

Firm Name Yale University **Location** Yale University Power Power Generation

Contact Person Bob Wildman

Flow Type: Output **Flow Name:** Fly ash **Quantity:** 10000 kilograms

Form: Solid **Purity:** 95% pure

Firm Name Connecticut Light and Po **Location** New Haven Coal Power Power generation

Contact Person

Flow Type: Output **Flow Name:** Flyash **Quantity:** 1000000 metric tonnes

Form: Solid **Purity:** Contaminated

Connecticut Light and Power

Location: New Haven Coal Power New Haven

Firm Name Brick Manufacturer **Location** Potential Brick Manufacturer Typical Brick Manufacturer: Average of 5 sample companies

Contact Person

Flow Type: Input **Flow Name:** fly ash **Quantity:** 10000 kilograms

Form: Solid **Purity:** 90% pure

Matchmaker! New Haven