Information and Service in Emergy Analyses

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ABSTRACT

As the interest of emergy researchers has in recent years been attracted to the evaluation of manufacturing processes, several issues have come to the fore. One is the input of human work and knowledge, or ‘services’, into a process. Another is the input of the accumulated legacy of shared knowledge or culture. A third is the controlling input of ‘communication’ from multiples sources in the information production hierarchy. Confusion begins with knowing what exactly is being evaluated. More confusion comes with quantification. At times, these three inputs are confused with each other. A fourth source of confusion is the accounting term, ‘services.’ Theories of information and emergy are complex and intimidating for researchers whose major interest and background is in engineering or manufacturing. No clear guidelines have been produced to aid emergy researchers regarding these somewhat daunting issues. Emergy researchers want a procedure to incorporate ‘information’ into their analyses. How can information be quantified? What theory and methods should apply? This paper will attempt to fill that need, to offer guidelines that address together labor and information in emergy analyses.

Information, ideas, knowledge, culture, these are big trouble for systems modelers. How can you represent these? How can they be quantified? How should we even think about them?!

Modeling Manufacturing

This paper will be addressed especially to the modeling of manufacturing processes, but it will also have application more widely. With the interest of LCA and other modelers in manufacturing, there is a perceived need to deal with the ‘information problem’.

For modeling manufacturing, it is felt that ‘inputs’ should somehow include the knowledge or ideas of workers. Inputs should include ‘How to’ knowledge for how to make something. Inputs should include software in all the computers. Inputs should include ‘loans’ or ‘stock issuances’ used to finance the factory. Etc!

This paper will propose that we need to think of information in at least three ways: Culture, Communication, and Services. For modelling ‘information’ inputs, confusion typically begins with distinguishing the three types. More confusion comes with quantification. A third source of confusion is the accounting term, ‘services’. This paper will attempt to sort this out, and in the end, to propose some guidelines.
‘How to’, Leave It Out

I will start with a dramatic proposal. When it comes to all the ‘design specs’, the ‘How to’ information for manufacturing an object, we can ‘leave it out’. You might say, my high-tech industry is a revolution, nothing like anything before. But your industry relies on precision machining techniques. You did not invent them. Your industry uses computer-controlled robotic systems. You did not invent that. Your high-tech widget is built in a factory. You did not invent that. Your factory depends upon computerized logistics and just-in-time delivery. You did not invent that. In fact, your factory was not even the factory invented by Henry Ford. It was expanded on a model of an artisan workshop. Which was elaborated from household production. And on and on.

This should make us wonder about ‘intellectual property’. We all stand on the shoulders of the millions before us. Or said another way, we all depend on the cultural ‘memory’ (emergy) of our past. In fact, research today suggests just how little each of us knows, and how dependent we are on the shared knowledge all around us (Muthukrishna and Henrich 2015, Sloman and Fernbach 2017).

But if that is the case, how can we leave it out when modeling manufacturing? I will come back to this topic in a moment. You will see that it certainly does not mean that we should leave out all ‘information’ inputs, or all ‘service’ inputs.

‘Services’ vs. the Others

We will begin to distinguish the three forms of information, (1) culture, (2) communication, and (3) services. ‘Culture’, or ‘Cultural information’ is everywhere. It is ancient, it produces the division of labor in society, the many roles, distinctive industries, manufacturing practices, ‘how to’, etc. The analogy is of ecosystem structure, a division of labor between countless living species.

The second form is ‘communication’ information. The products of regular conversation, and also the information ‘industries’ that people use to ‘communicate’ with each other. Products are ‘information objects’ that we use to control, coordinate, cooperate, attract, etc. Examples are conversation, social media, TV, recorded music, an academic paper, a law, etc.

The third form of information is ‘services’ information. For emergy researchers, ‘services’ was given a precise, operational definition by Odum (Odum 1996:58&230), and for many years has been incorporated into emergy analyses. Several different methodologies are used. They will be briefly reviewed below. The other two ‘information’ forms will be elaborated following that.

Clarifying ‘Services’

However, before we discuss the emergy services methodologies, it was mentioned above that the accounting term ‘services’ (or ‘service industry’, or ‘service sector’) is a source of confusion for emergy researchers. In the language of accounting, ‘services’ are ‘intangible goods’, such as legal advice, tourism, or home repair. Intangible goods are said to improve productivity, as in assistance with a tax form, or a medical checkup. For economists, ‘services’ have costs that appear on ledgers, which is of use to emergy researchers, though not as it is for economists.

For emergy researchers, the term ‘services’ has a very different meaning. It is any work and knowledge contributed to a process by people in the production of anything (not only ‘intangible’ goods). Linked to this operational definition of ‘services’ is an equally narrow role for ‘money’. For emergy researchers, all money has the single role of paying for the work of people, i.e., typically as they aid in the production and movement of some material or energy (emergy). Money moves between people in counter-current to emergy (Odum 1996:53).
Producing Timber

To clarify the uses of ‘services’ and money’ in emergy analyses, two simple examples will be presented. In systems modeling, ‘services’ can be any kind of work done in the production of something (not only ‘intangible’ work). In this first example (Figure 1), the work done by a variety of blue-collar laborers is called services. Human work is done in delivering goods, pumping and moving oil, and running the process needed to produce ‘timber’ as an output.

All of those work tasks are represented by the single ‘services’ source. Also, in this diagram, we see that money (dashed line) is not paid to nature. It is only paid to the people that mine or harvest the inputs from nature, and its source is people in the market who purchase the timber.

Service Industries

Money is also paid to people when people do indeed provide intangible goods, ‘services’ as defined by economists. In Figure 2, a ‘Service Industry’ produces a service sold in the market (e.g., financial or legal advice). The service leaves the boundary, and money enters in counter-current to the service flow. It then goes to the human services providers, the ‘Services’ source outside of the boundary, as in Figure 1. In fact, in this diagram, the money is also paying for the work done in providing flows of electricity and goods to the service industry, but as before, the money only travels to the workers, represented by the Services source.

In both examples, it is implied that money is somehow a measure of services value. Indeed, in emergy analyses, one important method for calculating services emergy is to multiply the money value by the emergy/money ratio of the country of the origin of the services (Odum 1996:81).
Figure 2. Service Industry.

Calculating Services Emergy

In energy modeling, the measure of energy ‘services’ is often money, as above. But it can also be measured in the energy expended by the worker. This is the second most common method for calculating services emergy. The worker energy is converted to emergy by multiplying by a transformity for human labor.

Average transformities for the energy provided in labor can be easily calculated for most countries. Here are some examples (Table 1). These can be used for rough estimates of services emergy for any worker.

Table 1. Service Transformities.

<table>
<thead>
<tr>
<th>Country</th>
<th>Transformity*</th>
</tr>
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<tbody>
<tr>
<td>Albania</td>
<td>8.11E+06</td>
</tr>
<tr>
<td>Argentina</td>
<td>1.47E+07</td>
</tr>
<tr>
<td>Armenia</td>
<td>1.70E+07</td>
</tr>
<tr>
<td>Australia</td>
<td>4.71E+07</td>
</tr>
<tr>
<td>Austria</td>
<td>4.19E+07</td>
</tr>
<tr>
<td>Azerbaijan</td>
<td>5.76E+06</td>
</tr>
<tr>
<td>Burundi</td>
<td>2.43E+05</td>
</tr>
<tr>
<td>Belgium</td>
<td>6.28E+07</td>
</tr>
<tr>
<td>Benin</td>
<td>1.49E+06</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>6.02E+05</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>8.37E+05</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>1.28E+07</td>
</tr>
</tbody>
</table>

* Calculated from the NEAD database for a sample of countries.
If a more precise emergy value is desired, Odum has calculated a range of energy transformities for US workers, based on their level of ‘education and experience’. This was calculated by taking the total US emergy and dividing it by the total metabolism of people located in six ‘scales’ of ‘education and experience’ (Odum 1996:232). Transformities are included in Figure 3(b) which is based on Odum’s original diagram. Figure 3(a) is a schematic representation of the total US nature-culture system, and is based on the diagramming convention proposed in Abel (Abel 2011), which includes scales for ecosystems, economic production, individuals or households, and cultural information production.

Figure 3. Calculating Services Emergy.
Abel (2010) calculated a larger but similar set of transformities for world workers (Figure 4). I make the point that social hierarchy depends on education (Odum’s focus), but also on the big three – economic capital, social capital and cultural capital – which we acquire largely from our parents and peers (Bourdieu 1977).

To avoid the difficulty of naming these scales, I proposed a mostly unlabeled hierarchy of transformities, separated by population orders of magnitude. This allowed me to further divide Odum’s large ‘Legacy’ scale into groups of smaller numbers of powerful individuals. My only labels are ‘World Poor’ at one end, and ‘Super Elite’ at the other. The term ‘Super Elite’ might be applied to the 1% of the 1%, or to charismatic leaders with millions of followers. Specific examples could be Ghandi, MLK, Bezos, Gates, Exxon CEOs or Wall Street bankers in the top 0.1%.

**How are Human Services Produced?**

As all things, human services are the product of a process. We can diagram that process. Figure 5 is a diagram of a production process of ‘people’. It is essentially the ‘socialization’ process of creating a person, and ‘services’ are the output.

In Figure 5, there are inputs to the production process of goods, electricity, and ‘communication’ information. Notice also ‘services’ coming from Parents, Teachers, Managers, etc., in the production and delivery of information, goods and electricity.

The interaction of these inputs produces the storage of memory (of knowledge and body experience) (also DNA). Services is the application of the memory storage as we perform work or deed, i.e., when you work you are using your learned knowledge and skills.
Communication

The next step will be to distinguish ‘services’ from communication. Culture is a ‘storage’ of information. In anthropology we now often call it ‘cumulative culture’, to highlight the great time depth of the storage, and the fact that it is slowly accumulating innovations.

In contrast, by communication, we can refer to the exchange of information between individuals. Most simply, we communicate in conversation. But we also communicate with the products of information ‘industries’ (Abel 2014). I have been exploring Odum’s ‘information cycle’ for some time (Figure 6), and its application to human communication.

Figure 5. The Production of Services. Notice that communication information includes discourse, social media, advertising, music, TV news, ritual, and formal education.

Figure 6. The Information Cycle.
Figure 7. Hierarchy of Information Cycles in Communication.

Figure 7 depicts the multiple scales of communication information production. Scales include conversation, but in addition the ‘industries’ of social media, advertising, ritual, TV, education, computer programs, scientific research, finance, legal codes, and others (Abel 2014).

The products of these ‘industries’, a song, a news story, a semester course, a software program, a book, a money concentration, a performance, a social media ‘post’, a law, a patent, etc, are all forms of communication. We saw above that some of them are information inputs to the production of people and their memories in Figure 5.
Communication Information in Manufacturing

What is the function of human communication? Human communication has many functions, perhaps each has a unique purpose, depending on the context. But these functions can be grouped into general categories, based on the intentions of the speakers (and system needs): Coordination, Cooperation, Attraction, and Control. It is maybe that last, ‘control’, which is the most general, and perhaps includes the others. Many processes require some level of human ‘control’, either in timing, logistics, or organization. When we look at the products of these communication industries, some immediately stand out as important contributions to control in manufacturing.

Figure 8 is a very general systems diagram of ‘manufacturing.’ It includes some typical communication inputs to manufacturing, patents, loans, laws, and software, produced in the hierarchy of forms of communication information.

In contrast, recall that the major communication information inputs to the production of people and their services in home, school, and work (Figure 5): discourse, social media, advertising, music, TV News, ritual, and formal education. We will keep this in mind when we make suggestions for future emergy analyses.

Figure 8. Manufacturing. Notice that communication information includes patents, loans, laws, and software.

Cumulative Culture

Finally, ‘cumulative culture’. Odum defines culture as “the shared information of a human society by which it operates”. Social scientists today use the term ‘cumulative culture’, to emphasize the great time-depth in the formation of culture. Odum calls this ‘the time required for cultural development’. However labeled, it is clear that, when we talk about culture, we are referring to a ‘storage’ of information, a storage of shared information, a concentration and refinement of information that required the work of thousands or millions of people over a great stretch of time.

Cumulative culture is the accumulated legacy of shared knowledge or culture. We see it especially as the existence of manufacturing traditions, the division of labor, or the history and existence of
institutions of all kinds. (Again, think of ecosystem niches, or species diversity). In manufacturing, you might think of the ‘design specs’, but cumulative culture is much more than that. It is the deep history of information that creates a manufacturing niche, within the total ‘ecosystem’ of cultural production.

Certainly, the production of an object requires information, the ‘design specs’, or ‘how to’ information. Where is the ‘how to’ information located? In the minds of workers and managers. In the proprietary data bases of the corporations. But more fundamentally, the ‘how to’ information is located, as I said, in the division of labor, institutions, and economic sectors, which have been evolving for thousands of years. As species of life have co-evolved for thousands of years in the structure of ecosystems, so have the skills and knowledge of the manufacturing of all human artifacts within the human economic system

### Cumulative Culture in Manufacturing

I will now explain that, for emergy evaluations, this ‘how to’, this cumulative culture, does not need to be evaluated. How can that be? Certainly, every manufacturing process includes the ‘how to’ information for producing the product. That knowledge may have a long history of creation, refinement, and evolution that has led to current manufacturing techniques. Think of the histories of soap production, or weapons manufacturing, or farm tools, or clothing, on and on.

Current ‘intellectual property’ laws cloud this picture, accentuating recent minor innovations for profit reasons. But the majority of the technologies that underlie any current widget have been developed over decades, centuries, or longer. So, how can that cumulative information not be an important emergy input to a manufacturing process?

### Biosphere Emergy

Brown and Ulgiati (2018) ask a similar question, ‘In evaluating the inputs to anything, perhaps an aluminum can, why do emergy analyses not include the total emergy of the geobiosphere since the beginning of Earth as we know it (4.54 E9 years)?’ After all, by definition, emergy is the ‘memory’ of all energy that went into the production of a product or service.

So have you ever wondered when reviewing an emergy analysis, ‘Where is that deep historical emergy of the biosphere?’ The answer [per Brown and Ulgiati] is that because that geobiosphere emergy is in ‘everything’, there is no need to carry along all those zero’s (i.e., 12E24 sej/y x 4.54 E9 yrs = 5.45 E34 or 34 zeros).

### DNA Emergy

This type of rationale is utilized in emergy analyses in one even more general case, though emergy researchers are probably again unaware of its omission. Over the years, many emergy analyses of agriculture, silviculture, swidden farming, etc, have been conducted. Typically, all inputs from nature and from the economy are included.

However, in no case has the ‘storage’ of genetic information in the plants or animals been added to the inputs? Why not? Certainly, the long history of genetic evolution that shaped and formed the genes of plant or animal are an essential input to any farming effort. Without that unique genetic material, the extremely valuable farming product would not exist.

In fact, if this is considered deeply, not only would the domestic plant or animal genetic material be required. But it could be that the entire genetic history of life, since its emergence and evolution, has led to this moment when fish, or timber, etc., genetic material is available for farming.

Odum said it this way, “Although species have evolved in fantastic variety, the main part of the genetic information of life is in common, shared by the millions of organisms. Genetics of life
culminating in human genes took a billion years to develop, a very long turnover time with a large transformity. The main essence of life has a large global territory” (Odum 2007:125).

And so, this is the answer to the question. When farmed organisms are the object of analysis, there are two options. One, include the emergy of evolution since the beginning of life. Or, two, leave it out.

In fact, this answer goes beyond farming. Evaluations of watersheds, dams, rainforests, wetlands, estuaries and every other ecosystem type that emery researchers evaluate are also obviously dependent on the genetic material of all life within their borders.

And so, again, the question becomes, why not include genetic information as an essential input to those systems? The answer, unpublished but per MB, is that the genetic information can be ignored. The alternative would be to include the evolution emergy of all life in every emergy analysis. That would lead to an emergy input of about E28. This would inflate all other calculations, without adding anything meaningful.

You may object, a fish has a unique genetic history, or a rainforest, or a wetland, or a desert. Does not the genetic material of that system deserve its own specific evaluation, its own unique quantification? Is not a rainforest more productive than a desert?

But this is where the grand picture of life on Earth is required, perhaps Gaia is a better description. Life on Earth is one product. In specific environments, it has evolved in this way or that, but each is ultimately dependent on the biosphere whole, and on life’s origins. The named ecosystems or biomes of the world are a division of labor in the total production of life. But none is more dependent on life or genetic material than another. And together, life from all biomes produces the world biosphere, that entity that functions together in so many countless ways to contribute to global maximum power.

**Structural ‘How to’ Information**

We could therefore ask, how is a fish like a factory? A factory, like a fish with DNA, certainly depends on the specific blueprint, procedures, knowledge for manufacturing its output, a widget. This is a portion of the ‘how to’ cultural information. But only a small portion. Cultural information, just like genetic information, is the product of evolution, cultural evolution on a global scale. No specific industry or institution is more or less ‘evolved’ than another. Each should be located within the division of labor in its region or biome of production. Which itself is located within the global production of humans, the global cultural system.

But again, you might object to say that my industry is high-technology, requiring a vast accumulation of complex information, does it not have a higher information input? The answer is that industries do not exist in isolation, just as one fish species does not. Every industry is part of a system, a division of labor, a human social and cultural system, in which all parts have contributed to the whole.

Therefore, as with genetic emergy, as with geobiosphere emergy, the total emergy of cultural information is in ‘everything’, at least within every human institution or industry. It therefore, need not be included in emergy analyses, carrying along all those ‘culture’ zeros to every human production process. In a phrase, leave it out.

**Accounting for Information**

So then, what ‘information’ emergies do we need to account for? We saw before that for manufacturing (Figure 8), these controlling ‘communication’ inputs could be very important: Patents, Loans, Laws, Software. In my opinion, these emergy inputs to manufacturing need to be included. If so, these should be a priority for emergy analysis. Currently none have been evaluated.

Suggestions could be made for conducting emergy analyses of these communication inputs. A single corporation, for instance, a law firm, could be researched and an emergy analysis performed. But maybe, the ‘sector’ approach would be better (Brown, Woithe et al. 1993, Brown, Cohen et al. 2006, Abel 2010, Zarba and Brown 2015). As in calculating ‘services’ transformities, you could apply the total
system energy to each sector or scale – software, finance, legal. You would divide the total system energy by the number of some appropriate object – laws used (cycled) in a year, money concentrations produced, computer programs written, technology patents issued. This would produce an average energy for a single information object of whichever type.

Other communication information inputs were identified in this paper in Figure 5, in the production of a person related to their ‘services’ output (which is later input to manufacturing). These communication information types have also (mostly) not been evaluated. Fortunately, for emergy researchers, there already exist two other reasonable ways (money and energy) to calculate human ‘services’. That should be sufficient.

And finally, the last form of human information, the storage of ‘cumulative culture’, by analogy with DNA, may be ignored. This ‘how to’ and cumulative culture information is of great interest for theorizing about culture, information, and even manufacturing (as in (Abel 2018, Abel 2018)). But for conducting emergy analyses, it is (thankfully) not required.

References


