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A THEORY OF WASTE AND VALUE

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ABSTRACT

Waste and value are ambiguous concepts, making it difficult to visualize where and how they occur in construction. This paper visualizes waste and value in construction at three scales: systemic, synergistic and discrete and from the perspectives of stakeholders: owners (strategic), middle managers (logistics) and field personnel (tactical).

This paper uses literature search, critical rationalism and theory building to graphically depict how waste is unknowingly embedded in construction design and production. This paper proposes that additional research is needed to measure synergistic and systemic waste and value. Visualizing waste in construction is the point of departure for those seeking to find and minimize or eliminate waste and create a theory for the discipline.

The authors assert that the cost of waste + cost of value = total cost, implying that, as the cost of waste decreases, the proportion of cost of value, vis-à-vis the cost of the project, increases. This paper is aimed at stakeholders who want to better understand how lean initiatives fit into the quest for value creation and waste elimination.

Keywords: Lean Construction; Planned Percent Complete; Theory; Waste and Value

INTRODUCTION

This paper asserts that there are three scales of waste: (1) discrete (quantifiable); (2) synergistic (the sum of waste is greater than its parts); and (3) systemic (waste resulting from a major contract breakdown). These scales of waste are interpreted differently by stakeholders, such as owners (strategic), planners (logistics) and workers (tactical). Furthermore, at the level of theory, waste is the inverse opposite of value since both waste and value are defined as vectors that have origin, magnitude and direction. The presence or absence of waste affects value and vice versa.

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METHODOLOGY

This paper uses grounded theory and visualization to construct an integrated analysis that is both interactive and reflexive, both contextual and conceptual (Knigge and Cope 2005). This method is based on Slocum (1999), who states that in the context of data exploration, "multiple representations" refers to the various methods of symbolizing data. Popper's 1972 theory of three worlds argues that objective knowledge can only be gained through symbols that have meaning. Visualization is a symbolic language that captures meaning the way that words, music, mathematics, and art capture aspects of reality.

LITERATURE SEARCH – THEORY OF WASTE

Waste is an ambiguous word and its presence in construction is even more elusive (Womack and Jones 2003; Alarcon 1977; Bossink and Brouwers 1996; Faniran and Caban 1998; Serpell et al. 1997). For example, there is time waste (Ilozor 2009; McDonald and Smithers 1998), material waste (Formoso et al. 1999; 2002a and 2002b; Tam 2008; Thomas et al. 2005), primitive technology waste (Chen et al. 2005), labor waste (Dainty and Brooke 2004), energy/resource waste (Kunde et al. 2005; Treolar et al. 2003), financial waste (Bell and George 1995), unrealized potential waste and defects (Mills et al. 2009); process waste (Serpell and Alarcon 1998); and risk waste (Sacks et al. 2009), among others.

Formoso et al. (1999) state "construction waste is caused due to insufficient use of equipments, manpower, resources or capital in larger than quantity which was required for production." The concepts of efficiency, productivity (Harrison 2007; Abdell-Wahab et al. 2008; Walsh et al. 2006; Rao et al. 2004; CII 1990; Crawford and Vogl 2006), benchmarking (Costa 2006; Park et al. 2005), performance (Meade 2006), competitiveness (Flanagan et al. 2007; Momaya and Selby 1998), and metrics (Eastman et al. 2008) have evolved over time as ways to measure waste (NRC 2009).

The following factors are typically considered in value and waste analysis: productivity, cost and schedule growth, profitability, predictability, variability, relationships, innovation, wages, health and safety, business ethics, environmental performance and whole service life. Therefore the metrics, although simple at the task-level, can be complex (Baccarini 1996 and Bertelsen 2003) at the project-level and even more complex at the industry-level where multi-defined, multi-measured, multi-layered, dependent, relative, dynamic and process are inter-related, as noted by Flanagan (2005) and Gidado (1996). Ohno (1988) has defined seven wastes in manufacturing that Lean construction has adopted: Overproduction, Conveyance, Inventory, Waiting, Processing, Motion and Correction. Lean construction case studies report these seven manifestations in the production of buildings. Koskela (2004) observes that the first five refer to the flow of material and the last two to human work. Ultimately all construction production factors and metrics may be boiled down to cost and time, although a pure reductionist view would even fold time into cost (Shawhney et al. 2004) as a variable of value and waste.

This paper creates a taxonomy of waste with three components: systemic, synergistic and discrete. These three levels of measuring waste parallel Chapman and Nurty's (2008) and Meade et al.'s (2006) levels of industry: project and task. Meade's term for industry, however, is Organization and National Economy. All the scales of waste are highlighted when construction production processes break down. This affirms Heidegger's (1962) observation that when a system breaks down, the background of that system becomes highlighted, that is, it goes from hidden to transparent. In our case, all waste scales are manifested for a brief time, particularly those involved in the breakdown analysis.

VISUALIZING WASTE

Construction is the actualization of an owner's needs, wants, and desires through a contract of expectations visualized in agreements, drawings, models, and specifications. Lately, this visualization has taken the form of nth dimensional models that incorporate time and cost and are open to an infinite number of parameters. Other project dimensions await visualization, such as performance requirements (Augenbroe and Malkawi 2003), safety and risk analysis (Hafey 2010), lean (Sacks et al. 2009 and 2010), facility management functions (Fernandez-Solis 2010 submitted to Facilities), and waste. Just like we visualize a project's process, we need to be able to visualize and differentiate these three scales of waste embedded in a project. Why? These three scales create a framework that makes the items in the waste lists transparent and visible.

Sacks et al. (2009) visualize waste in work flow in order to support lean construction with the goal of waste reduction, but the study does not visualizes the scales mentioned above, the type of stakeholders, or the use of waste. Sacks (2010) observes that visualization of production processes enables workers to perceive the process state and measures of improvement. Visualization and the concept of transparency (Formoso et al. 2002b) are pre-requisites to, first, motivate a paradigm shift among all stakeholders (owners, designers, builders and supply chain) and second, codify lean construction requirements and computer aided visualization tools (such as BIM). This would make the paradigm shift consistent, reliable and predictable. Visualization is a pre-requisite for the application of scientific quantitative methods, (Knigge and Cope 2005). The adage that "you cannot improve what you do not measure" is now "you cannot measure what you do not visualize." This paper visualizes three scales of waste and values: discrete, synergistic and systemic.

DISCRETE WASTE

Discrete waste, that is, material waste, is classified by type, weight (Gavilan and Bernold 1994), volume (Alwi et al. 2002; Ekanayake and Ofori 2004) and cost (Love and Li 2000; Love et al. 1999).

Discrete waste exists at the task level. NRC (2009) states that: "task-level metrics are leading indicators and are commonly used by contractors and subcontractors who must evaluate the efficiency of their workforces on a daily or weekly basis and make adjustments so that problems on active projects can be detected and corrected quickly". Task refers to specific construction-related activities, such as placement of concrete or the installation of mechanical systems. Most task-level metrics include explicit measures of output for specific tasks and the labor hours required to complete the task.

Most waste measurements are at the discrete level. Table 1 is a compilation of waste measurement research at the discrete level.

Table 1. Types of Waste Research

Research Method	Alwi et. al (2002)	Bossink et. al (1996)	Daintv et. al (2004)	Ekavanake (2004)	Faniran et. al (1998)	Formoso et. al (2002)	Garas et. al (2001)	Gavilian et. al (1994)	Ilozor (2009)	Leng (2004)	McDonald et. al(1998)	Mills et. al (2009)	Polat et. al (2004)	Poon et. al (2004)	Serpell et. Al (1997)	Tam et. al (2008)	Treloar et. al (2003)
Field Observations		X				X		X			X						
Questionnaire Surveys	X		X	X	X		X		X	X			X	X		X	
Interviews			X														
Other (Analyzing existing databases)												X			X		X

SYNERGISTIC WASTE

Synergistic waste occurs at the project-level. NRC (2009) states that project–level data is a function of individual components (e.g., materials, systems), processes (e.g., type of contract, type of project delivery system), and tasks that are interrelated and concatenated. Both synergistic value and waste are created by the interrelation of production processes, systems, and components at the hands of humans working in collaboration. Synergistic waste (lack of human performance and collaboration) collaterally affects trust, confidence, reputation and other social and financial aspects as if by contagion, through the intricate web of contract agreements dictated by the legal-economic system.

SYSTEMIC WASTE

The greatest waste in construction (by magnitude), systemic waste, becomes visible when there is a contractual breakdown between parties that ends in mitigation, arbitration or litigation. Part of the reason for waste at the systemic level is that traditional contractual arrangements have given rise to economic situations that have stable sub-optimal behavior situations (Sacks et al. 2009). Fortunately, systemic breakdown is not the norm, but when it does occur, the magnitude of value transferred from the project to the legal system is typically significant.

UNDIFFERENTIATED WASTE

NRC (2009) states that the U.S. Census includes data for *value of construction work* (defined as value of construction produced for sale), *value added by the industry* (defined as value of construction minus the costs related to subcontracts and materials used) and *value of construction put in place* (defined as a measure of the value of construction installed or erected at the site during a given period). Currently, all these values include the costs of waste (discrete, synergistic and systemic) embedded and undifferentiated. In other words, the industry, as defined by the North American Industry Classification System (NAICS) does not differentiate embedded waste in its accountability of value. The systemic nature of construction embeds construction waste in its production processes (discrete, synergistic and systemic) when compared to other industries (Fernandez-Solis 2009; Shen et al. 2004), except in the case when processes break down as noted above.

RELATIONSHIP OF WASTE AND VALUE

Formoso et al. (1999) define construction waste as “any losses produced by an activity that generate direct or indirect costs but do not add any value to the product from any point of view to the client”. Hence, there is a relationship between waste and value (Best and De Valence 2002) that needs exploration. In an abstract sense, waste can and does exist by itself. Logic dictates that in real world construction, the possibility of a value proposition is a pre-requisite for the possibility of waste. Therefore, in this paper waste and value are two facets of construction production.

This paper argues that discrete, synergistic and systemic wastes exist in the same ambit where discrete, synergistic and systemic values exist, where waste is the inverse opposite of value. According to Palmer (2003), both waste and value, as aspects of reality, are vectors and thus they have origin, magnitude (in this case inverse) and direction (in this case opposite) that characterize the value and waste aspects of production (see Figure 1).

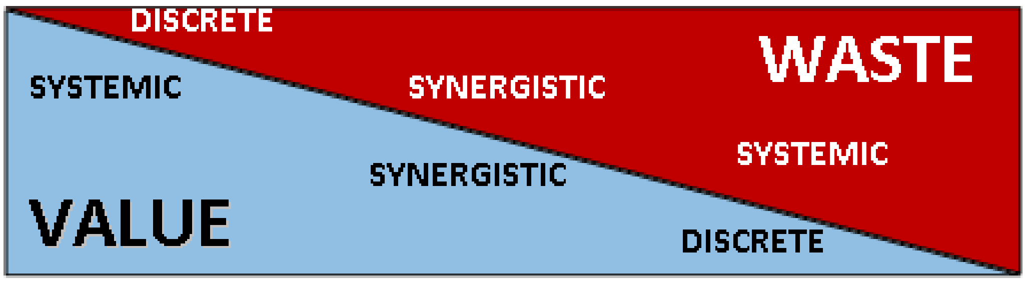

Figure 1. Visualization of the Inverse-Opposite Relationship of Value to Waste in Construction.

In other words, just like production processes have discrete, synergistic and systemic value scales, the production process contains the inverse opposite scales of waste. The scales of value are: discrete value (from materials, products, labor, overhead, profit); synergistic value (from added value due to reputation, market differentiation, management, safety records); and systemic value (from local, regional, national and global economics, the industry historical trends, technological progress, etc.) (see Table 2).

Table 2. Type of Value and Waste in Relation to Scales

Scale Type	Value	Waste
Discrete	Material, Labor, OandP…	Material, Labor, Cost, Time, Quality
Synergistic	Reputation, Trust, Confidence	Reputation, Trust, Confidence…
Systemic	Local, Regional, State, National and global economics, utilities, Demand and Supply market, Forces…	Project Trend (Discrete), Systemic Nature of Industry(generic)

ELABORATION OF THE WASTE SCHEMA

If discrete and synergistic waste persists and becomes a trend reaching a critical point (not defined in the scope of this work), systemic waste may develop that is both discrete (project related) and generic (industry related). The contractual agreements of all parties and the systemic nature of the industry (Fernandez-Solis 2009) are examples of where generic waste resides. The magnitude of construction waste at the systemic level is extremely difficult to ascertain and is a source of debate (Allen 1985; Berger 2005; Dubois and Gadde 2002; Fox et al. 2002; Low 2001).

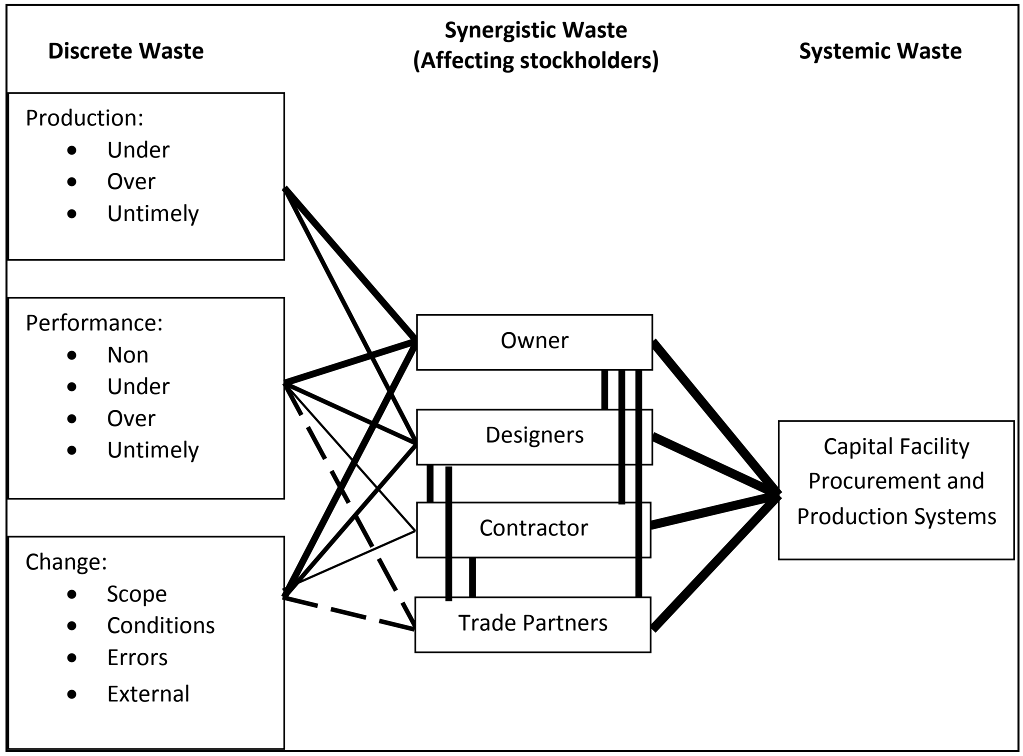

Figure 2. Framework of Discrete, Synergistic and Systemic Waste Relations.

Figure 2 showcases three common types of events that create waste in manufacturing as well as in construction: production (over, under and untimely); performance (none, over, under and untimely); and changes (scope, conditions, errors and due to external circumstances). This list is not exhaustive, but encompasses a Pareto list of major waste causing events.

These events require intervention by stakeholders (owners, users, designers, contractors, trade partners, manual laborers, suppliers, manufacturers, operators, regulators, financial institutions, legal representatives, insurance and bonding companies, among others) in order to address the condition and hopefully find the root causes, generate lessons learned and adapt the process to minimize or eliminate repetition. Once a waste condition becomes obvious and stakeholders are involved, the waste becomes synergistic; in other words, a waste that is greater than the sum of discrete wastes.

The US EPA 2000 has acknowledged the need to reduce waste and published a strategy for 50% waste reduction in construction (NIST 2004; FFC 2007; Tripplett and Bosworth 2004; Tulacz and Armistead 2007). For the purpose of this paper, we accept the EPA's 50% goal as the benchmark of achievable waste reduction (by increases in performance and efficiencies or by actual waste reduction). Similarly, the NSTC (1995) report proposed the following goals for construction:

- Fifty percent reduction in delivery time;
- Fifty percent reduction in operation, maintenance and energy costs;
- Fifty percent less waste and pollution;

- Fifty percent more durability and flexibility; and
- Fifty percent reduction in construction work illness and injuries

We may expect that the impact of each scale has different consequences. For example, discrete waste may be contained at the level of execution (the field level) and corrected immediately (the goal of partnering a technique and an approach, as advocated by the US Corps of Engineers - Barlow et al. 1997; Bennett and Jayes 1998; Larson 1995). In this case, discrete waste can be considered additive. However, when discrete waste requires the involvement of several stakeholders, the opportunity for synergistic waste can be expected to increase. In this case, synergistic waste can be considered to be multiplicative and contagious. When patterns of synergistic waste exist and trends become reality, the probability of adversarial conditions increases along with contractual breakdown. At this scale of waste, project value is transferred from the project system to the legal system (see Table 3).

Table 3. Stakeholders, Value and Waste

BCO Players Value/ Waste Scale	Owners	Middle Managers	Field Personnel	Equivalent Mathematical Function
Discrete			X	Addition
Synergistic		X	X	Multiplication
Systemic	X	X	X	Exponential

STAKEHOLDERS' UNDERSTANDING OF WASTE

Each Building Construction Organization (BCO) survives by acquiring and performing new work that is largely based on past performance by an organization that is responsive, responsible and does timely work. The organization can therefore be considered consistent, reliable and predictable. Organizational survival, in the 2010's, is characterized by being able to do more with less, and the only way to achieve this is by increasing efficiencies. NRC (2009) defines efficiency improvements as "ways to cut waste in time, costs, materials, energy, skills, and labour."

In the 1990's, Lean Construction brought a manufacturing focus on waste elimination linked to a theory of transformation, flow and value in construction wrapped in a continuous improvement process. However, each construction stakeholder has a different interest and therefore, a different perception of waste and its effects on the overall operation. Very few have an overarching concept of waste as a system that works against profitability, efficiency and risk.

In the building industry, there are three major categories of stakeholders: client, service organizations and production organizations. Clients may be private (North American Industry Classification System lists construction types from which a typology of private organizations can be deduced) or public (governmental agencies, e.g. US General Services Administration--GSA). Service organizations are composed of designers (e.g. architects and engineers) and net of consultants and general contractors. Production organizations are those performing field productions, such as contractors with self-performing capabilities, subcontractors (now referred to as trade partners), suppliers and vendors. Waste per Project Management Body of Knowledge (PMBOK) and lean construction research, is inherent in all three stakeholder categories (see Figure 3).

Figure 3. Stakeholders and type of organization players.

Within each of these stakeholder groups there are three main categories of players: owners, middle managers and field personnel. For example, client organizations have upper management (e.g., owner, principal, president), but they also have middle managers who handle finances/ accounting, planning (due diligence), and project management, and field personnel, such as an owner representative who interacts with the service organizations and oversees the construction progress. Service organizations, likewise, consist of upper management--owners, principals, presidents; middle managers, such as project architects and the design and construction document production team of architects, engineers and consultants; and field personnel, such as contract administration architects, superintendents and project engineers (CPWR 2007; Green 2002). General contractors' middle management encompasses schedulers, estimators, project managers, accountants, office personnel. Lastly, production organizations likewise have three main categories of players: upper management--owner, principals, presidents; middle managers--estimators, schedulers, support personnel; and production--fabricators, installers and foremen, among others.

Upper management concerns are characterized by Kerzner 2009 as strategic (mission, vision and objectives of the organization), financial (organizational survival and growth) and concerned with risks (financial viability of the project in the context of the organization's strategic plan), due diligence (zoning codes, utilities) bonds, insurance, contingencies, and retainages. Middle management's concerns are characterized by logistics: bridging strategic and tactical plans that minimize risk and maximize profits through change management (systemic nature of the industry); planning and monitoring processes related to production (risk, safety, cost, time and quality); and a focus on making plans reliable, repeatable and predictable. Production organizations and personnel focus on tactical plans–-adapting plan implementation to minimize risk and maximize profit at each work task with a focus on responsive, responsible and timely performance of promises and expectations in a dynamic ad-hoc setting.

Two additional items affect how waste is perceived: frequency of work and how BCO's set up organizational performance. Stakeholders may have multiple projects per year, or only a few. The number of projects that any given organization performs per year is related to organizational experience and the rate at which it accumulates a body of knowledge, that is, the internalization of lessons learned as a way to identify and eliminate waste. Organizational performance is characterized as command and control (push) or Last Planner System (pull)—or a combination of both. Command and control is the norm in the industry, representing the way work has always been done. Pull system (i.e. Last Planner® System of Production Control; LPS) is the Lean challenger that identifies waste in command and control and proposes alternatives that require a BCO paradigm shift.

SYSTEMIC WASTE - THE LOOSE COUPLING OF STAKEHOLDERS

Teo and Loosemore (2010) state that the loose coupling of stakeholder organizations is a source of waste by nature of the duplication of effort, miscommunication and misunderstanding at the transitions and transference (inputs and outputs) of information. Systemic waste is at the industry-level.

Koskela has noted that production in construction is based on transformation, flow and value, while manufacturing primarily accomplishes the transformation of materials through production systems. Transformation attributes are: moving, assembling, storing/retrieving, and comparing. Flow is both physical and informational (such as through Information Technologies) and some additional attributes of flow are: communicating, assembling, transforming, storing/retrieving, and displaying. Value, however, is only achieved when the customer's request is fulfilled by the performer and is declared acceptable. While transformation and flow are readily optimized, value, as in the Work Flow Loops (WFL) mentioned below (see Figure 4), is the sole performer of BCO production.

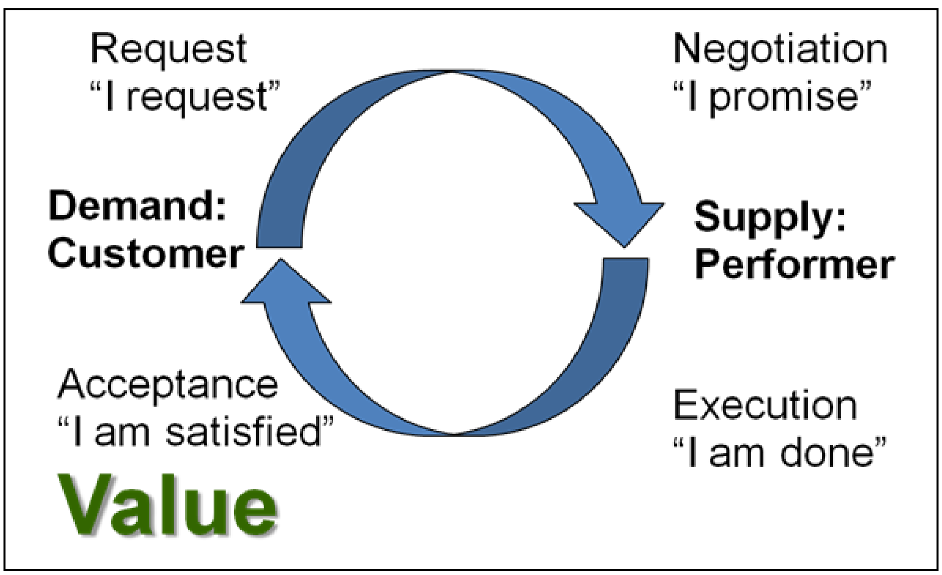

Figure 4. Commitment Work Flow Loop.

In construction production, a relatively large number of WFLs are created for a prototype project (see Figure 5). Note that this WFL has similarities with the continuous improvement loop of Do-Check-Plan-Act but with the difference that, instead of being continuous within one party, the continuity is achieved by repeating it among multiple parties (different stakeholders), due to the systemic nature of construction. This multiplicity of contracts increases the probability of breakdowns that become contagious and therefore cause systemic waste, a situation that integrated contracts address (Lichtig 2005).

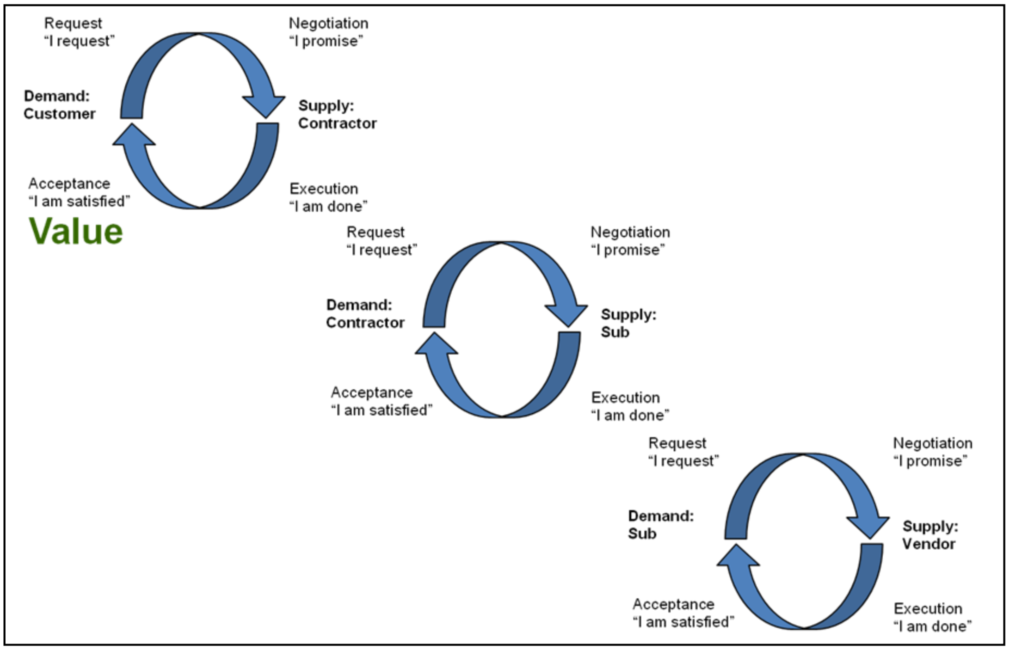

Figure 5. Web of Temporary Relationships.

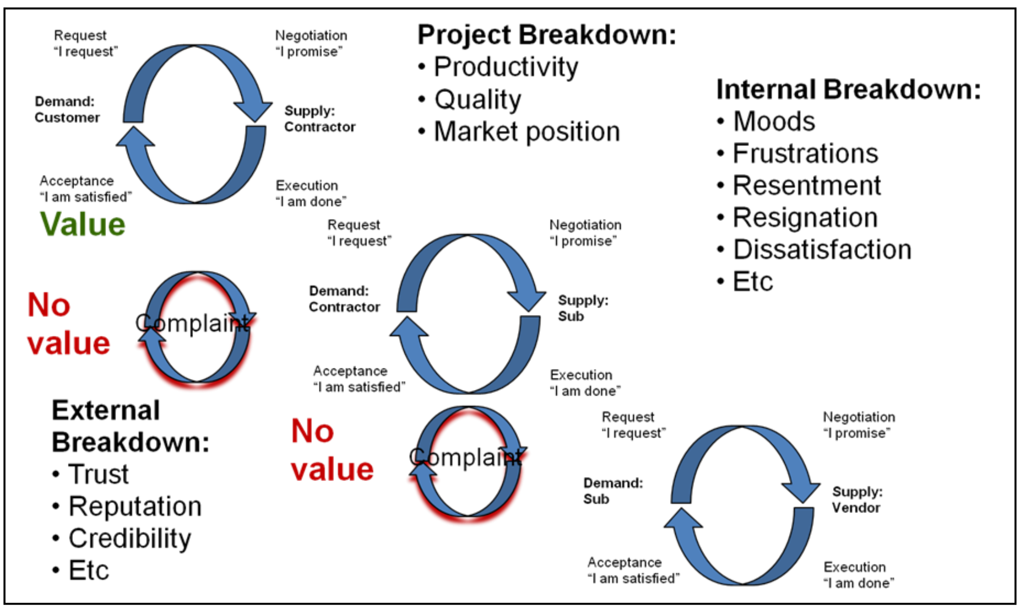

Figure 6. Breakdowns – One Source of Waste.

These loops form a web of temporary relationships with only one value creating event: customer acceptance of the final product. In this scenario, events with no or negative value take place and detract from the only source of value. Some of these events and consequences are described in Figure 6. Project breakdowns, internal breakdowns and external breakdowns are examples of synergistic waste affecting stakeholders even when they come from discrete events. Methods are needed to map, measure, track and manage the flows, outputs, defects, cycle times, complaints, Requests for Information (RFI's), punch list, customer satisfaction and other indicators of waste that comprise synergistic waste.

IMPLICATIONS OF ELIMINATION OF WASTE

When waste is entangled in the project delivery process, it also becomes "embedded" in the project because resources that could have been used for the generation of value were instead consumed for the generation of waste.

The implications of waste elimination are clear. Because the cost of waste + cost of value = total cost of the project, as the cost of waste decreases, the total cost of the project approaches the cost of value. The owner then has two choices: (1) maintain the original budgeted cost of the project and replace the extracted cost of waste with additional value, or (2) remain with the original budgeted value of the project and therefore reduce the final cost of the project to the cost of the original budgeted value. In other words, eliminating waste leads to either an increased percentage of value per same project cost, or reduced project cost for delivery of the same amount of value. The chosen outcome is the decision of the owner and project team.

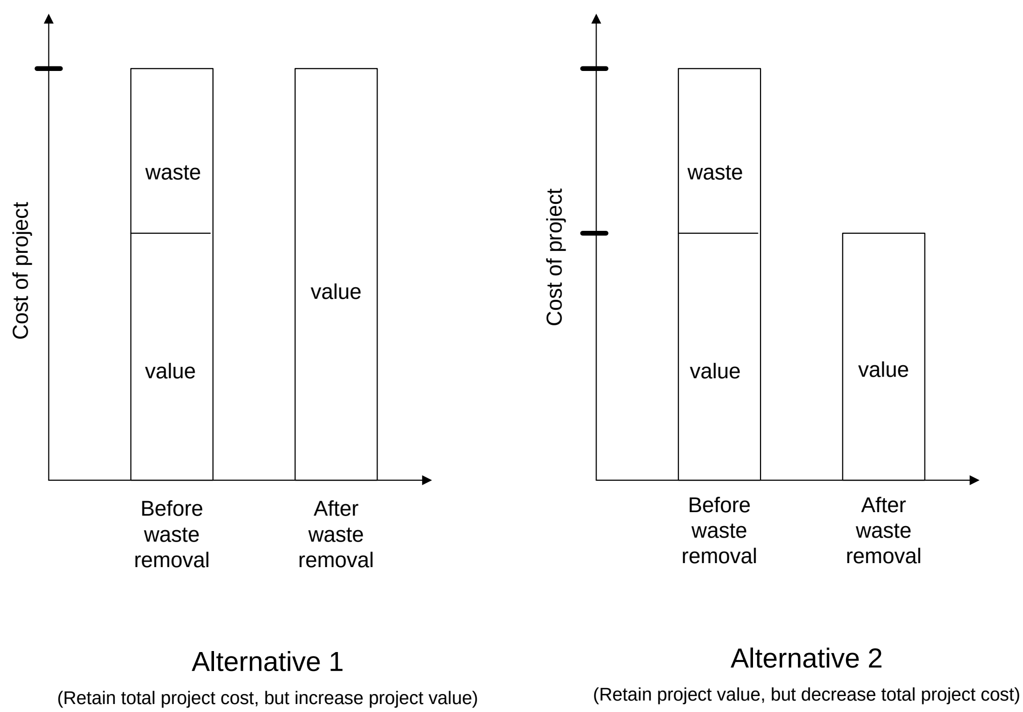

Figure 7. Implications of the removal of waste: Two response alternatives.

CONCLUSION

While it is idealistic to assume that all waste can be deleted from a project (thus creating a product and process with absolute optimum value), we can visualize a project whose value and waste are intrinsically related. Different stakeholders (strategic, logistic and tactical) have differing interests in waste elimination and value creation that require a clear visualization of the different scales as a tool to better understand the interplay between waste and value.

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