A Simulation System for Developing and Evaluating Implementation Strategies for Knowledge Management Systems (KMS) in Small to Mid-size Enterprises (SME)

Abstract

Companies create and use information and knowledge every day. The problem all companies have is to efficiently discover that knowledge, capture it, share it, and use it to gain competitive advantage in the marketplace. Although there has been extensive research performed on aspects of these issues, and some attempts to model Knowledge Management, to the best of my knowledge no one has developed a design language to create simulations specifically for understanding the flow of knowledge in a given organization. This paper describes a simulation system designed to provide small to mid-sized enterprises (SME) with a means to understand the impact of organizational structure, KM investments, and culture on the flow of information. The system's design is based on graphical constructs that will allow users a quick means to represent the organization in terms of the key points of generation, discovery, capture, and sharing of knowledge and the barriers that exist among these process points. Once a user graphically represents the knowledge process flows and barriers, the system will allow input of parameters from the users. The simulation itself produces measures of efficiency and effectiveness and sensitivity analysis of the parameters. The initial graphical model of the organization can subsequently be modified and its parameters changed to reflect proposed organizational changes to improve knowledge flows, or to reflect the future growth of the company. These subsequent simulations are relevant to an organization's efforts to determine the appropriate strategy for current and future KMS efforts.

Keywords: Simulation, Knowledge Management, Small to Mid-sized Companies

Introduction

Corporations are faced with tradeoffs every day in the process of deciding where best to invest their capital. Information System (IS) departments serve a critical role in advising the company on the best means to use IS and Information Technology (IT) to achieve its strategies while limiting capital, time and risks. A Knowledge Management System (KMS) is one IS solution that may be considered important to a company's strategy. Implementing a KMS is generally a large, complex, and costly undertaking, although it may be approached stepwise. This raises the question of just what is the correct sequence of KM Infrastructure, mechanisms and technologies, and processes to implement. There is little research that has looked into strategies related to the sequence of systems and processes for knowledge processing (Beccera-Fernandez, et al., 2001). However, it is clear a KM strategy is needed to minimize risks and uncertainties with budget and to encourage acceptance (Jennex and Olfman, 2000). Strategies must account for critical success factors that will affect new system acceptance and in the case of this paper – knowledge flows and use. Key factors that influence the acceptance of a KMS have been identified in the literature: management leadership and support, culture, information technology, strategy and purpose, measurement, organizational infrastructure, processes and activities, motivational aids, resources, training, and human resource management (Wong & Aspinwall, 2005). Another critical factor, richness of knowledge (Davenport & Prusak, 1998), is associated with linkages and context. The recognition of that richness should be accounted for in the rankings of packets by the knowledge search capabilities (Poston and Speier, 2005). The extent of linkages is quantifiable and may be useful as a predictor of user acceptance of a KMS. Although no study appears to have looked at the differential ranking of critical success factors based on company size, I believe it may be safe to assume there are factors that will be affected. In particular, any factors associated with the creation, input, and linking of knowledge in the KMS are likely to be influenced by the number of personnel available to create, input and link that new knowledge. The more people available to do so will certainly increase the amount entered. Beccera-Fernandez et al., (2004) indicates that organizational size has a direct influence on various KM processes. Smaller organizations would differ from large organizations in that knowledge sharing occurs primarily through socialization, knowledge application through instructions and knowledge discovery through combination and socialization. Large organizations rely more on routines and exchange to accomplish the same. This company size factor provides a strong reason for researching Small to Midsize Enterprises (SME) organizations since they exist at that transition point where the knowledge flows and processes are likely to be in transition.

SMEs are a critical part of the U.S. economy, accounting for 96 percent of all companies in the U.S. (Moss, 2003) and approximately 75 percent of new employment (SBA, 2001). A SME, with less capitalization than large companies, may face considerable risk in taking on a large IS project such as the implementation of a KMS. This research will strive to provide information that may be valuable to those SMEs facing a decision on whether to move forward with implementing a KMS. Knowledge of key success factors, especially quantifiable ones, may greatly improve their ability to make informed decisions on whether to move forward with a KMS project. However, quantifiable factors alone do not provide enough information for sound decision making. Accounting for the interactions of those factors and how they operate in a specific entity can provide a much stronger foundation for effective decisions.

A SME's organizational knowledge is limited relative to that of larger organizations, and when an employee leaves, they potentially leave with a relatively larger share of the organizational knowledge. Thus it should be an imminent concern to SMEs to find a means to capture knowledge and protect itself from loss of valuable knowledge, especially in those SMEs with extensive knowledge based work. Good examples of such SMEs are Fabless Semiconductor Design companies and Biotech companies. There are other advantages that a SME can realize from an effective KMS: reduction of repetitive solutions to the same problem, reduction of redundancy in knowledge based activities, make knowledge available quickly and easily, and increase employee satisfaction by enabling greater personal development and empowerment. The key advantage, however, is to obtain a strategic advantage over competitors (Knapp, 1998). Knowledge-based resources may be essential to providing a sustainable competitive advantage because of the difficulty competitors have in duplicating it (McEvily & Chakravarthy, 2002).

There are two categories of knowledge that IT systems must support in some fashion. Explicit knowledge, is generally in written form, and can be read, distributed, stored and manipulated in many ways for advantage (knowledge base, data warehouses, DSS, portals, etc). The second form of knowledge, tacit knowledge, encompasses perspectives, know-how, expertise and context-specific skills and is not easily put in writing (Takeuchi & Nonaka, 1995). Therefore, it requires entirely different systems to assist in its creation and dissemination. IT tools helpful with the creation and transfer of tacit knowledge are those that encourage dialog: links, communities of practice, portals, E-mail, groupware, intranets, the Internet, and videoconferencing (Scott, 2000). Both types of knowledge require effective linking to context and other knowledge to be of high value to the using community. Jennex and Olfman (2000) point out that a strategy needs to be in place to ensure the integrity of linkages: adequate resources for creating and updating, security to ensure validity and accuracy, encouragement of users to make it a part of daily activity, and to monitor changes to the KMS itself.

Problem Statement

The research question pursued by this paper is: Does the extent and value of knowledge, its linkage, and structural barriers to knowledge flow change as a SME grows? The value in this research is in providing a mechanism for the SME business community to use in evaluating potential strategies when considering or moving forward with the implementation of a KMS. A company that knows the volume, linkage, and structural barriers to knowledge flow, can then understand the timing of investments in resources to support an evolving KMS. This research may also prove valuable to those involved in the design of future KMS simulation tools: to create a more effective interface to allow users to capture their corporate knowledge structure and the parameters for factors affecting the flow through that structure. This research and model could also be employed to understand large companies as well. However, SME's provide an advantage in the simulation because they experience the point where the flow of knowledge through personal contact becomes impacted by growth.

Concept

The artifact is based on the concept that knowledge is created or acquired and then must flow to others who can apply it in the same or new ways, or combine it with other knowledge to create new knowledge. Nonaka (1994) identified four forms of knowledge capture, which in the context of this paper, can be conceptualized as knowledge flows: socialization, externalization, combination, and internalization. This knowledge flow is the key to the artifact model (see figure 1.). The knowledge flows along these pathways as information packets of tacit or explicit information. Socialization is the pathway for tacit information to flow between people. Sometimes this tacit information can be converted to explicit information and flow through the pathway of externalization. Combination occurs when someone is able to take explicit information and add more explicit information to it. Lastly, information that is received as explicit and converted into tacit occurs through internalization. Thus there are several ways that information packets can flow from someone motivated to exchange that knowledge to someone motivated to receive it. Something must induce the flow of knowledge. This paper assumes a push-pull concept. Push represents the input and capture of created knowledge and the willingness to share it. If there is someone who has the desire for that knowledge, they will pull it towards themselves. The model also represents the fact that there are barriers to the ease with which knowledge flows from those who create and capture it to those who desire it. Examples of barriers that may exist in an organization's flow of knowledge are:

1. Physical: employees less likely to interact frequently because they are separated by walls, buildings, geography.
2. Too few employees: few packets of explicit information being entered in a KMS.
3. Employee density: as a company grows, it becomes less likely that each employee will have equal opportunity to interact with every other employee – this in turn will slow the flow of tacit knowledge in the company.
4. Culture and language: communication of information may be limited by poor ability to understand one another or for cultural reasons that do not encourage sharing for reasons such as loss of power.
5. Lack of motivation to share or use knowledge.
6. Perceived "Usefulness": When the users do not receive an adequate amount of relevant information, they will use the system less. When more information packets are present in the system, the users will find it more useful.
7. Information Systems Infrastructure: lack of proper KM mechanisms and technologies.
8. Security, and others.

There may are also exist "value accelerators" that will improve the ability of an information packet to move through the barrier more readily. Examples of value accelerators are:

1. Linking of packets to other packets: improving context or broadening to other contexts.
2. Knowledge Repositories: storage of explicit information packets in a readily searchable form.
3. Email: will increase the flow of knowledge among those employees who may not have the chance of meeting face-to face.
4. Brown Bag Lunches – open discussions and storytelling to socialize tacit information.
5. Linking of competence to packets: providing links to experts who can provide additional details and context related to particular information packets.
6. Expert systems and A.I.: Sophisticated systems that aid the search for key information .
7. Data warehousing and Data Mining: providing the tools necessary to consolidate key information and look for unexpected relationships in the information.
8. Communities of practice: Online discussion with others interested and dealing with similar issues – provides for give and take of explicit information.

The permeability of the barriers and the value of the knowledge will determine how effectively the knowledge flows from creator to user. These barriers and value accelerators will vary from organization to organization. The model must allow for the selective inclusion of the relevant barriers and value accelerators and adjustment of their respective parameters.

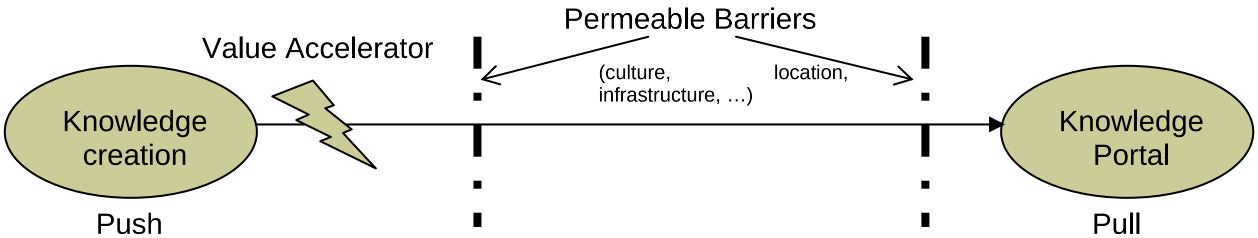
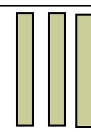
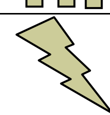
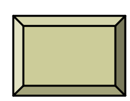
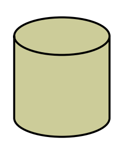
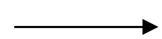


Figure 1. Conceptual Model

This research develops a simulation system using the above concepts. The system includes: a set of graphical constructs representing the structural characteristics that influence knowledge flow in an organization (see Table 1), the capability to simulate the knowledge flows of that structure, and the means to evaluate alternative structures and strategies. The graphical constructs serve a purpose analogous to objects in object oriented programming and contain methods and parameters. In a given instantiation, the methods determine the context of the construct (object) in the organization's knowledge flows and determine which parameters will be necessary to properly represent it in the simulation.

Table 1. Graphical Constructs

Permeable Barriers (Physical separation, Cultural, Language, Incentives, Management support, Security, Information infrastructure, etc.)	
Value Accelerators (Linking of packets, Linking of expertise, Communities of practice)	
Portals (Capturing, Adding value, Accessing)	
Knowledge Management Technology Modules (Information packets, Directory of competencies, KB, AI, Expert Systems, OLAP, Data mining, etc.)	
Knowledge Flows (Socialization, Externalization, Combination, and Internalization)	

The process proposed for using such a simulation system entails working with a SME to understand the knowledge flows, barriers, value accelerators, and portals that exist in the company. These constructs will determine the parameters necessary to configure the system's algorithms (percent of Tacit vs. Explicit packets, number of employees, number of packets generated by employee, etc.) and distributions (probability of a useful packet of information being found, impact of the number of employees on socialization, etc.) to properly model the SME's KMS structural characteristics. A discrete-stochastic simulation, using the model and parameters will simulate the flow of information packets throughout the organizational structure as modeled. A representative baseline will be developed by adjusting the construct parameters until the flows and usage rates approximate those measured by the organization. This baseline will be stored for comparison to models representing changes to the organizational structure (KM infrastructure, technology and mechanisms, and processes). The comparison of simulations will allow for an understanding of sensitivity of the knowledge flows to changes in the organizational structure and the associated costs/benefits. The organization may then develop a better informed knowledge management strategy.

Artifact Construction

The simulation constructed to represent the above model concepts was accomplished using iGrafx simulation software and is composed of the following components:

1. Knowledge Packet generator
    a. Poisson random number generator
    b. Percent of Tacit versus Explicit packets
    c. Prioritization of packets (determination of packet value)
2. Barriers
    a. Employee Density (Socialization pathway)
    b. KMS usefulness (Externalization pathway)
3. Value Accelerators
    a. Scheduled brown bag meeting (Socialization pathway)
    b. Email (Externalization pathway)
    c. Knowledge repository (Externalization pathway)
4. Receiver of Knowledge Packets

Knowledge Packet Generator

The knowledge packet generator controls the time between the creation of information packets produced each day. The interarrival time is based on the Exponential distribution and adjusted to account for the number of employees. The Exponential distribution has repeatedly been found to be a good approximation of the time between arrivals (information packets being generated) (Render et al., 2003). The key assumption associated with the use of an Exponential distribution is that the arrivals are independent of one another. Although there may be circumstances where two people generate information packets at the same time because of collaborated content, this is probably rare and not a serious constraint in the use of the Exponential distribution. The Exponential probability function is:

$$P(x) = \frac{1}{\beta} e^{-x/\beta}$$

The mean interarrival time is β (in days) and x is the given service time (in days). β is adjusted each simulation according to the number of employees. Table 2 lists the values of β per number of employees in the company for the simulation.

Table 2. The value for β given the number of company employees

Number of Employees	Value for β
5	.5
10	.3
20	.2
50	.15

This table is based on the observation that a small company has frequent interactions among its members and with that stimulation of ideas and knowledge. Also, a small company is generally composed of founders who have considerable expertise and inventiveness. Thus a company of five may generate information packets twice per day on average. As the company grows, other employees are brought in for support functions and may not contribute new information as frequently. The time between new packets will decrease because there are more employees, however, the rate of new information generated per person will be less. This reduction in the rate of generating new information per person may also be driven by the new employees being less informed in the technology or having less cognitive capacity to generate knowledge than the initial founding team. The values provided in Table 2, and all subsequent tables, are based on limited personal observations and would need to be adjusted based on expert opinion and empirical observations for any specific company to be simulated.

Each information packet is randomly determined to be tacit or explicit and will, respectively, be directed to either the socialization pathway or the externalization pathway of the model. Since there are only two options, the Bernoulli distribution was selected for random assignment. The Bernoulli distribution will assign a given percent of the information packets as either tacit or explicit based on a provided probability of one of these occurring. This probability will change over time as the number of previously generated explicit packets increases. As more explicit packets enter and reside in the KMS, the usefulness of the system will increase because the users will have a greater likelihood of locating valuable packets of information. The percent of tacit and explicit packets will be adjusted in the simulation to increase the probability of explicit packets being created as the volume of existing explicit packets grows. This is accomplished by adjusting the Bernoulli distribution based on Table 3:

Table 3. Distribution of explicit packets given the number of employees

Number of explicit packets	Percent explicit packets to generate
0 - 250	0.2
251 – 500	0.3
501 – 1000	0.4
1001 – 2000	0.5
2001+	0.6

The last function of the knowledge packet generator is to assign a priority to represent the value of a particular packet just created. Not all packets are created equal. Some have more valuable content that will be desired by one or more people in the company. The normal distribution is used to represent the assignment of priority which has a range of 1 to 127. It is not unreasonable to assume that in any company, there are some low value and some high value packets, but in general most will be somewhere in between in value. The normal distribution should reflect this condition reasonably well.

Barriers

There are several barriers in this model, two of which will be implemented in the evaluation instantiations described below. One barrier will be placed on the socialization pathway and represents a barrier to information flow caused by employee density. It will be found in all four instantiations. The other barrier, KMS usefulness, will be placed on the externalization pathway in the last two instantiations. The employee density barrier addresses the observation that the communication of ideas flows unimpeded in a small company but less so as the company grows. Although there are many reasons for this, the employee density barrier is concerned with the decrease in flow of tacit packets due to more people. As the employee population increases, there are too many people to meet on a daily basis, which, therefore, decreases the probability of running into the person with the right packet of information. The priority of a packet also plays a role in this barrier. A high priority packet will stimulate a person to tell it to more employees and thus increase the likelihood of the packet getting to the right person. The impact of the barrier in the model represents a delay in the transfer of a packet, which depending on its priority may range from a portion of a day to its never reaching another company employee. This barrier is simulated by the following function:

*Delay due to Employee Density = Packet priority * (Normally distributed random number selected from between the numbers X and Y) * Employee multiplier function*

The numbers X and Y are equal to 1 and 3, respectively, in the instantiations evaluated in this paper, but can be adjusted depending on the variability of desired delays. The employee multiplier function is used to provide a value to calibrate the packet wait time based on the number of employees and is represented by Table 4.

Table 4. Employee multiplier table

Number of Employees	Multiplier
0 - 5	0.5
6 - 10	1.5
11 – 20	1.5
21 – 50	2.5
51+	4.0

The KMS usefulness barrier will be implemented in the externalization pathway. The function used to simulate this barrier has parameters representing the packet priority, number of employees, number of explicit packets in the system, and a random generator. The result of this function is a delay attributed to an explicit packet.

*KMS Barrier delay = Priority * (5/# employees) * delay based on number of employees * (Normally distributed random number selected from between the numbers X and Y)*

Although the priority can range between 1 and 127, for purposes of this function, it is normalized to a range of 1 to 12 with 12 being the highest priority. The numbers X and Y are equal to 1 and 3, respectively, in the instantiations evaluated in this paper, but can be adjusted depending on the variability of desired delays. The delay based on the number of employees is represented by Table 5. The table is used to increase the delay when there are fewer packets in the system. The users will perceive the KMS to be of low value to them when there are few packets and use it infrequently. This is because the probability of there being a packet the user needs is very low when there are few packets. Therefore, the explicit packets initially entered into the system may be unused for a long period of time until the users see an adequate base of packets to search through and find useful.

Table 5. Usefulness Delay based on number of packets in the system

Number of packets in the system	Usefulness delay factor
0 - 100	20
101- 250	18
251 – 600	15
601 – 1000	12
1001 – 1500	8
1501 – 2000	6
2001 – 5000	3
5001+	1

Value Accelerators

Just as both the socialization and externalization pathways may have barriers, they may also have various value accelerators. The value accelerators perform the function of increasing an information packets priority. The higher the priority, the more rapidly the packet will pass through any barriers it encounters. There are three value accelerators used in the evaluation section of this paper: Brown Bag Meetings, Email, and Knowledge Repositories. The Brown Bag Meetings serve as a value accelerator in the socialization pathway by providing a time and place for employees to exchange ideas and build on each others knowledge. This is accomplished in the simulation by a function that increases an existing tacit packet's priority. The Brown Bag Meeting value accelerator is represented by a function which takes into account the existing priority of the packet as well as a randomization component.

*Brown Bag Value Accelerator = Existing Priority * (Normally distributed random number selected from between the numbers X and Y)*

The numbers X and Y are equal to 10 and 50 respectively in the instantiations evaluated in this paper, but can be adjusted depending on the duration and variability of desired delays.

The Email Value Accelerator increases the value of explicit packets in the externalization pathway by increasing their priority. This has the subsequent effect on movement through barriers as seen above in the Brown Bag Value Accelerator. The increase in priority is based on a randomness component plus the number of information packets being sent and viewed. The accelerator assumes that as the email system is used more frequently, the probability of receiving a valuable packet will increase. The Email Value Accelerator is represented in the simulation by the following function:

*Email Value Accelerator = Existing Priority + ((Normally distributed random number selected from between the numbers X and Y) * Probability of finding a Good Packet)*

The numbers X and Y are equal to 10 and 50, respectively, in the instantiations evaluated in this paper, but can be adjusted depending on the duration and variability of desired delays. The values used in the simulation of this paper are found in Table 6.

Table 6. Probability of receiving a good packet

Number of Explicit Packets	Probability of receiving a good packet
0 – 100	0.05
101 – 250	0.1
251 – 600	0.2
601 – 1000	0.3
1001 – 1500	0.55
1501 – 2000	0.65
2001 – 5000	0.85
5001 +	0.90

The last value accelerator is the Knowledge Repository. This value accelerator also operates by increasing the priority of explicit packets. A knowledge repository allows for packets of information to be stored and easily searched. This in turn allows packets to pass from the point and time of creation to an end user more rapidly than by email alone. This effect of the knowledge repository is simulated by the following function:

*Knowledge Repository Value Accelerator = Existing Priority + ((Normally distributed random number selected from between the numbers X and Y) * Probability of finding a Good Packet)*

The numbers X and Y are equal to 50 and 100, respectively, in the instantiations evaluated in this paper, but can be adjusted depending on the duration and variability of desired delays. As is the email value accelerator, the probability of finding a good packet is captured in Table 6.

Receiver of Good Packets

This last function in the simulation gathers statistics on how many packets, either Tacit or Explicit, were selected and the average length of time they were in the system prior to selection. This function only counts those packets that have a priority higher than 60. This gate can be adjusted for any given simulation. The packets as initially generated, receive priorities normally distributed between 1 and 127, so a value of 60 establishes that about 50 % of the packets will make it through at some point in time. The percent that ultimately make it through will vary depending on the length of the simulation and more importantly on the number of value accelerators each packet encounters. This follows from the logic that as you add value to your KMS (value accelerators), it will be used more often and thus more packets will be located and used for multiple purposes.

Evaluation Methodology: SME Model Instantiation comparisons

The concepts and simulation model developed above will be applied to a theoretical SME environment for the purpose of evaluation. A basic model (see Figure 2) will be developed that can be modified to represent alternative configurations of KMS infrastructure for the SME. The model will be adapted by addition of barriers, value accelerators, and parameter changes to reflect four alternative KM infrastructures for the SME. The artifact will be evaluated by comparing simulations of these separate SME organizational structures of barriers and value accelerators. The four instantiations evaluated in this study are:

1) *Instantiation #1 - Baseline SME organizational structure:* This instantiation will consist of the socialization pathway (tacit packets) with a barrier (Employee density) and an externalization pathway (explicit packets) with one value accelerator (Email). This organizational instantiation represents one of an organization with few initial personnel, and a poor KM infrastructure and technologies. It is reflective of a small startup company with few employees and little infrastructure.

2) *Instantiation #2 - Enhanced socialization pathway:* This instantiation builds directly on the preceding one by adding one value accelerator to the socialization pathway. In this situation, the additional value accelerator (Brown Bag Lunches), will represent a means to increase the flow of tacit knowledge by regular open exchanges of knowledge that might not happen by simple meetings in the hallway. This communication helps to promote the flow of knowledge through the employee density barrier found in this instantiation and instantiation #1.

3) *Instantiation #3 - Initial externalization pathway*: This instantiation builds directly on the second instantiation by adding a barrier to the externalization pathway. The barrier is titled “Usefulness” and represents that a KM system provides little “usefulness” when the number of explicit information packets available for searching is low. As the number of packets in the system increases, so does the probability of finding a useful packet. The barrier’s permeability increases as the number of packets increase.

4) *Instantiation #4 - Enhanced externalization pathway*: This instantiation will build on the third instantiation by adding a value accelerator (Knowledge Repository) to the externalization pathway. The value accelerator will improve throughput of knowledge packets by allowing for storage and future use. It also adds value by allowing for better categorization to aid in the search for specific information.

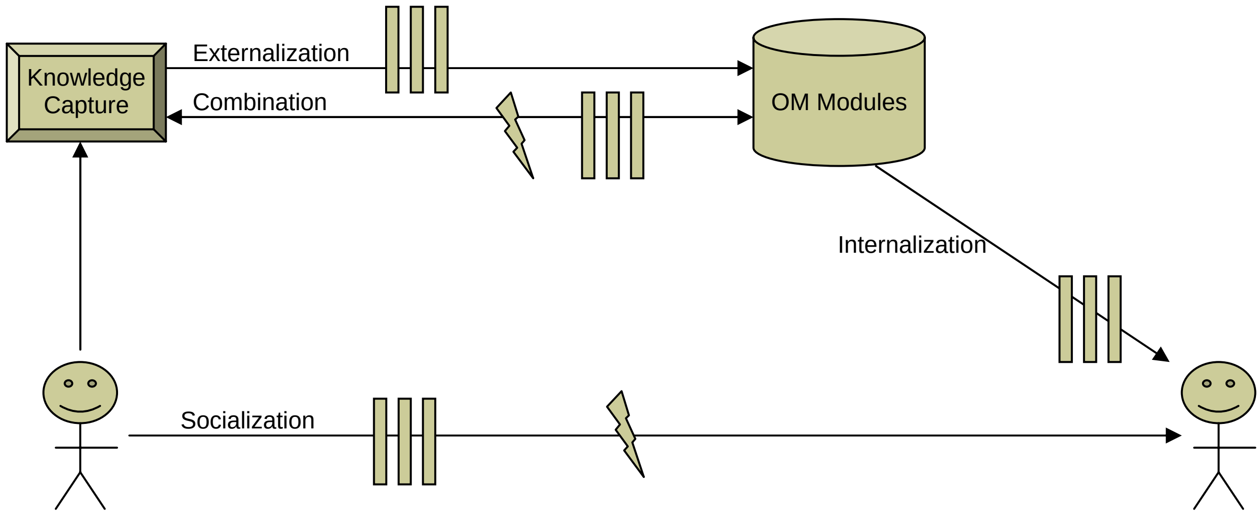


Figure 2. Basic Model

Each of the four above instantiations will be simulated 20 times: four categories of company size (5, 10, 20 or 50 employees) times five categories of the number of days (50, 100, 250, 500, and 1000). The results collected by each simulation will be the average time each packet spends in the system and the average number of packets received per person per day for both tacit and explicit packets. These key indicators of the efficiency and usefulness of the system will be plotted to evaluate the effectiveness of the model. The four instantiations represent a sequential improvement that one might expect to see in a SME over time. The first instantiation represents the baseline and perhaps could be considered a very early stage startup. The second instantiation represents an improvement to the socialization pathway. This difference can be addressed by the following hypotheses:

H1a: The value accelerator implemented in instantiation #2 will significantly reduce the average time tacit packets spend in the system over that of instantiation #1.

H1b: The value accelerator implemented in instantiation #2 will significantly increase the number of tacit packets received per person per day in the system over that of instantiation #1.

Instantiation # 3 represents the inclusion of a barrier on the externalization pathway to account for low usefulness of a KMS until a critical mass of packets are available for searching and finding valuable information. The fourth instantiation installs a knowledge repository to improve the usefulness of the KMS. This leads to the following hypotheses:

H2a: The value accelerator implemented in instantiation #4 will significantly reduce the average time explicit packets spend in the system over that of instantiation #3.

H2b: The value accelerator implemented in instantiation #4 will significantly increase the number of explicit packets received per person per day in the system over that of instantiation #3.

Results

The data from each simulation was collected in a spreadsheet for analysis and graphing. The data collected for each of the four instantiations was associated with their simulation specific parameters of the number of employees and the number of days simulated. The key statistics collected for each were: 1) the average time until a "tacit" packet reached a user of that packet, 2) the average time until an "explicit" packet reached a user of that packet, 3) the average number of "tacit" packets received by a user each day, and 4) the average number of "explicit" packets received by a user each day. The following figures report this data and are used to validate that the model is operating as instantiated.

The first set of figures (Figures #3 – #7) look at the baseline instantiation. This first instantiation, as detailed in the above evaluation section, incorporates an Employee Density Barrier and an Email Accelerator. The expectation for such an instantiation is that we would see evidence that the larger the employee population is, the longer the average time a tacit packet takes getting to the user of that packet. This might occur for two primary reasons: 1) as a company brings on more employees, some will be in support roles and not likely to be large contributors of new knowledge, and 2) the original small team, which had a relatively rapid exchange of that sharing, now are spending time managing and working with the new employees and less time exchanging new information. Figure 3 shows us that our expectations are met. The line for 50 employees shows an average increase of 20 days per packet in the system – about a 400% increase from when there were only 5 employees. The expectation of a longer time through the system was met, but is the difference seen here too excessive or maybe not excessive enough? I believe this may be excessive because as a company grows larger, subgroups form around job responsibilities and the need for similar information. So perhaps a less drastic difference might be more realistic.

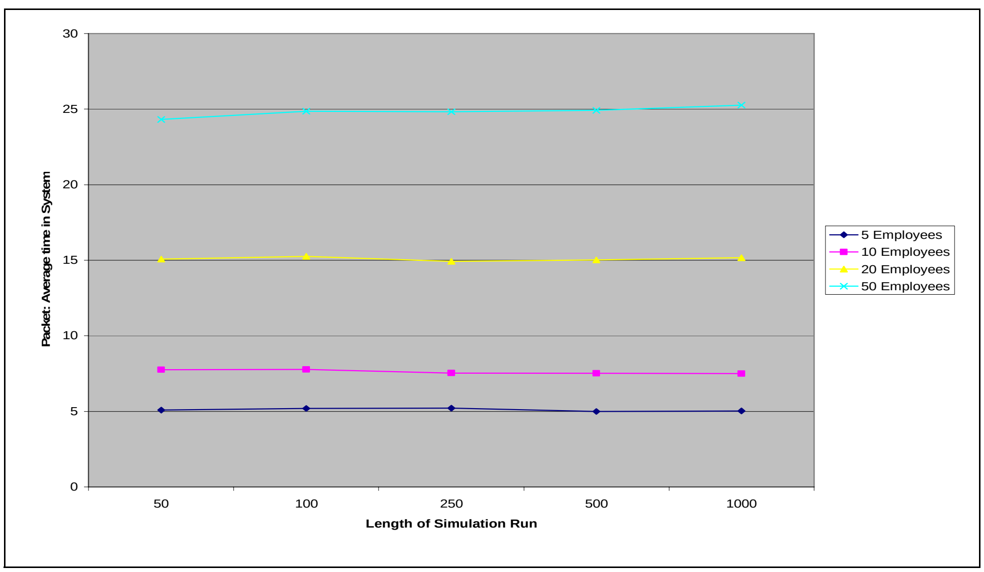


Figure 3. Instantiation #1 – Tacit Packet Average Time (days) in System

Figure 4 looks at the impact of this baseline instantiation on the flow of explicit packets. Since this instantiation does not have any barriers to explicit packets flowing through the externalization pathway, we would expect the time spent in the system to be invariant to the number of employees and the number of days simulated. Other than initial random noise, which disappears after about 250 days, this expectation seems to be met.

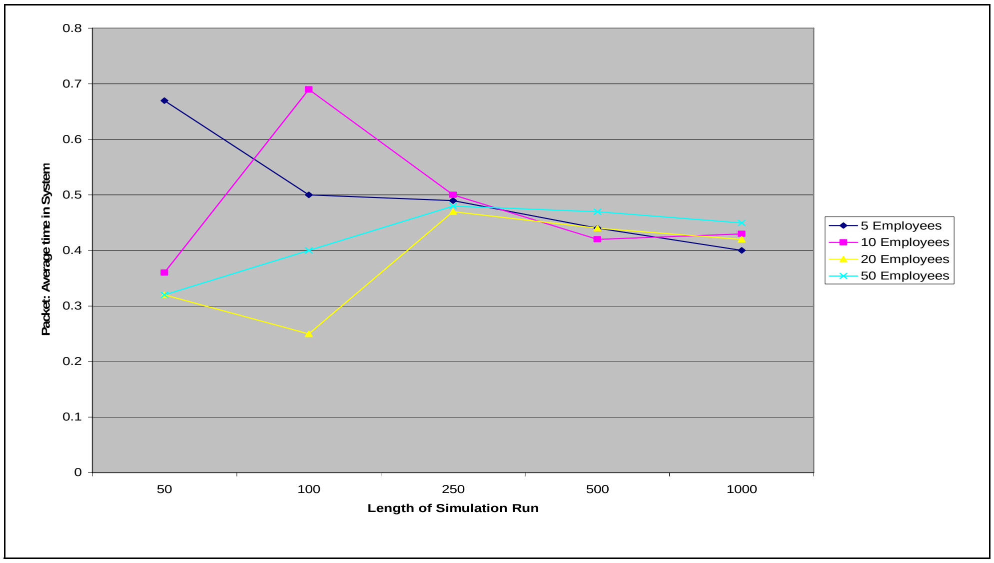


Figure 4. Instantiation # 1 - Explicit Packet Average Time (days) in System

The next two figures look at the number of packets per person per day received. Figure 5 shows this for the tacit packets and Figure 6 for the explicit packets. The expectations are that the number of tacit packets per person per day should be highest with a small employee population and lowest with the larger population. This is because in a smaller group there is more interaction and opportunity for exchange of information. As the group grows, the odds of a person with a valuable packet of information running into the right person who should receive that packet, decreases. This is what the figure validates. What is also apparent in this figure is a downward slope for all lines. This is also expected. The downward slope is due to the transition over time from primarily tacit information flow to one of an increasing proportion of explicit packets. Initially there are few explicit packets generated, but as the number of days of simulation increase, more explicit packets enter the system. The more explicit packets in the system, the more interest the users have in looking for those packets, which further encourages the production of explicit packets as all members see this value.

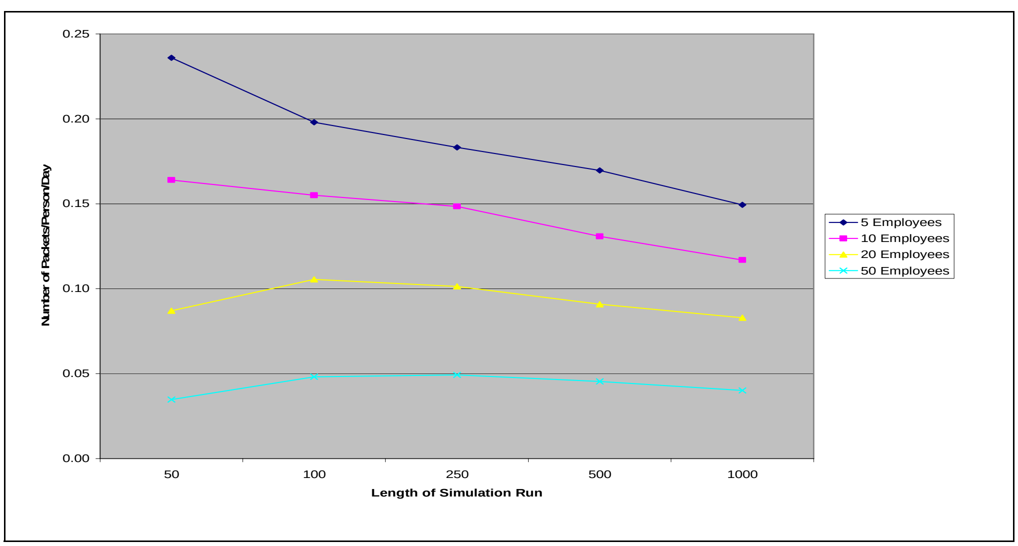


Figure 5. Instantiation # 1 – Tacit Packets/Person/Day

The externalization pathway carries the explicit packets and in instantiation #1 there are no barriers in this pathway. We would expect to see an increase in explicit packets over time. As more explicit packets are accumulated - the "usefulness" of the KMS increases and proportionately more explicit than tacit packets are generated by users. This is validated in Figure 6. This Figure also highlights the effects of adding new personnel as the company grows: 1) as a company brings on more employees, some will be in support roles and not likely to be large contributors of new knowledge, and 2) the original small team, which had a given level of sharing and relatively rapid exchange of that sharing, now are spending time managing and working with the new employees and less time exchanging new information. The figure illustrates this effect as a distinctly lower increase in packets per person per day for a company with 50 employees relative to that of the smaller companies.

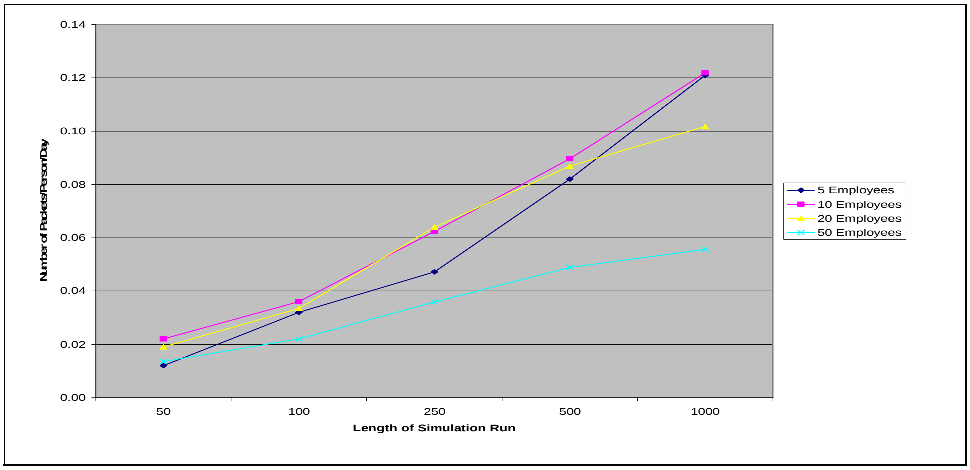


Figure 6. Instantiation #1 – Explicit Packets/Person/Day

The next figure looks at the second instantiation, which adds in a value accelerator: Brown Bag Lunches. This accelerator offers a means for a company to improve the flow of tacit packets, which will become more crucial as the company grows. When Figure 3 is compared with Figure 7, it can be seen that the number of days a tacit packet spends in the organization decreases. This comparison validates the expectations of the impact of the value generator both in terms of its effect on the time spent in the system and also on the greater value to a larger company.

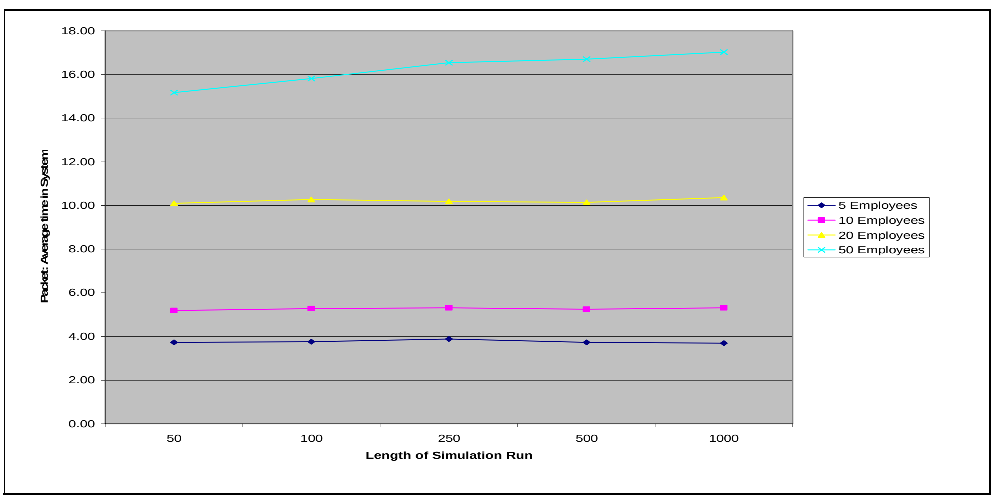


Figure 7. Instantiation #2 – Tacit Packet Average Time (days) in System

Figure 8 can be compared with Figure 5 to understand the effect of the brown bag value accelerator on the number of packets received per person per day. This comparison validates, that as expected, the average number packets per person per day increases due to the beneficial impact of the brown bag lunches on facilitating tacit information exchange.

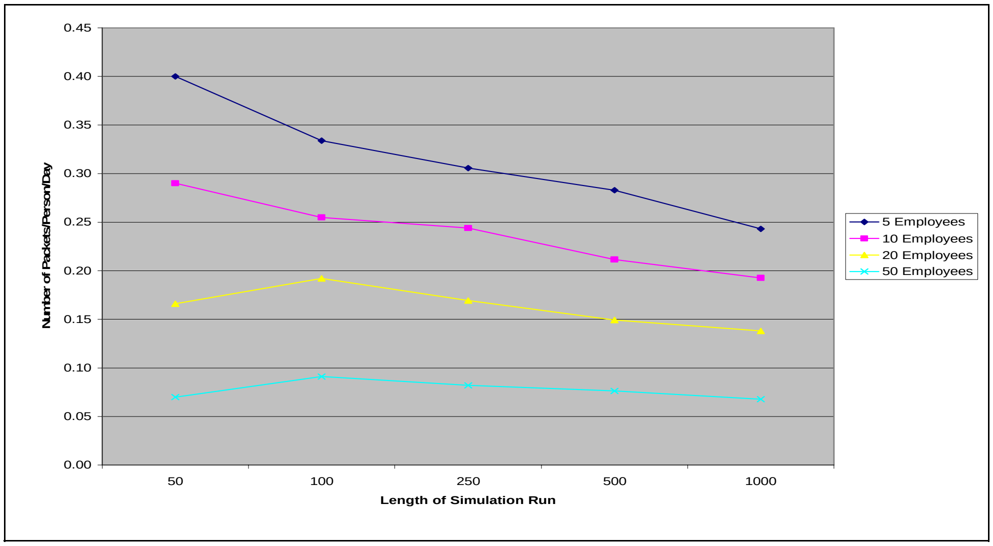


Figure 8. Instantiation # 2 – Tacit Packets/Person/Day

The third instantiation adds the barrier: KMS Usefulness. The purpose of this barrier is to reflect the impact perceived usefulness has on actual use of the system. If the users do not perceive the system as useful, because the information desired is not available, then they will not use it. The premise of this barrier is that as more explicit packets enter the externalization pathway and build up, the perceived and actual usefulness will increase. Users will have a greater likelihood of locating the information they require in a bigger pool of packets. By adding this barrier, the expectation is that the average time an explicit packet spends in the organization will increase to a point (critical mass), and then begin decreasing as more use of the system occurs. This is validated in Figure 9.

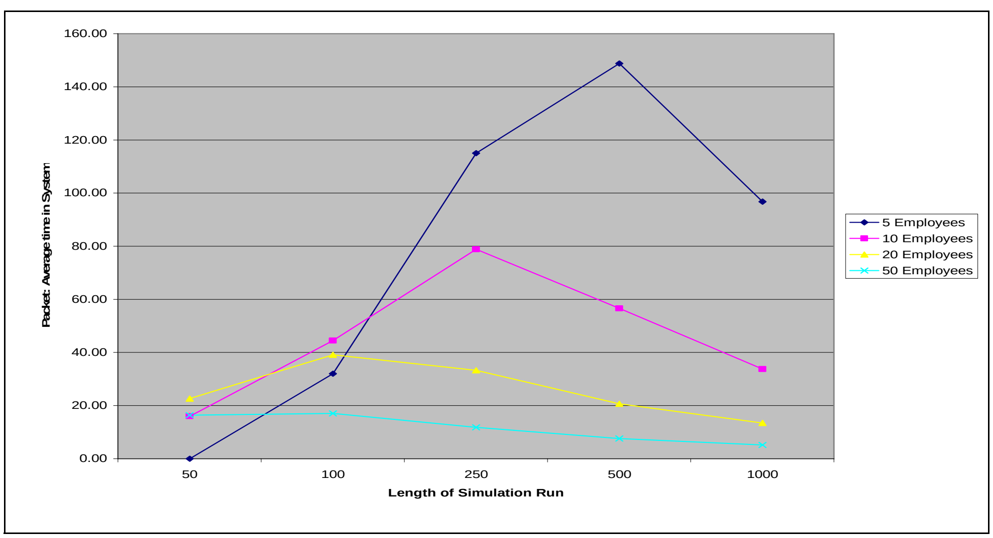


Figure 9. Instantiation #3 – Explicit Packet Average Time (days) in System

The effect of adding a value generator (knowledge repository) to the externalization pathway occurs in the simulation of the fourth instantiation and is seen Figure 10. The figure looks similar to Figure 9, but the scale is shifted downward representing a faster throughput of packets in the organization. This was expected and validates the externalization pathway for barriers and accelerators.

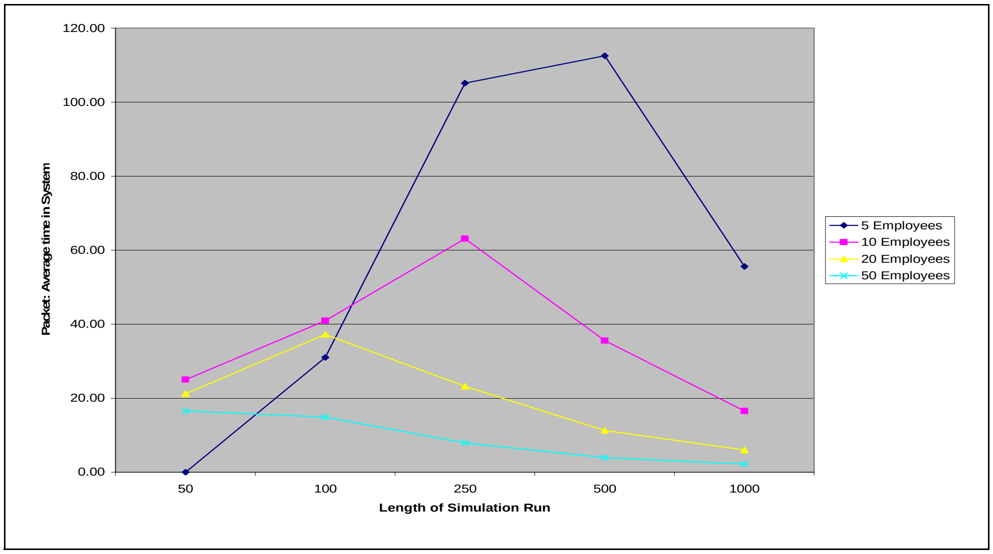


Figure 10. Instantiation # 4 – Explicit Packet Average Time (days) in System

Table 7. Summary of results

Hypothesis	**Supported/Not Supported**
H1a: The value accelerator implemented in instantiation #2 will significantly reduce the average time tacit packets spend in the system over that of instantiation #1.	Supported
H1b: The value accelerator implemented in instantiation #2 will significantly increase the number of tacit packets received per person per day in the system over that of instantiation #1.	Supported
H2a: The value accelerator implemented in instantiation #4 will significantly reduce the average time explicit packets spend in the system over that of instantiation #3.	Supported
H2b: The value accelerator implemented in instantiation #4 will significantly increase the number of explicit packets received per person per day in the system over that of instantiation #3.	Supported

Contribution to Research

The process of developing and validating this artifact identified numerous areas where future research is required:

- How does one measure the number of tacit packets?
- What is the ratio of tacit to explicit packets?
- What factors establish the explicit/tacit ratio or cause it to change?

- What are the real barriers to flow of information and knowledge and what factors define them?
- What are the means to improve the flow of information through barriers and how are these means defined?
- How are all these questions affected by size, age, and industry of the company?

The design itself is an iterative process and as new theory or data on parameters becomes available the design will be improved. Using the knowledge gained from this study will provide insight into what researchers might look for and what they might see when studying knowledge flows in situ.

This research also provides some support that the organizational structure, number of employees, the type of information packet, and time can be modeled to understand how these variables interact. Future research may provide additional insight into how organizational structure, KM infrastructure, motivators, physical workspace, organizational climate, and actual behaviors work together to produce "usefulness" in a KMS for a SME.

Conclusion

This model with its four instantiations is an initial attempt to demonstrate that a simplified model of knowledge flows in a company is possible and provides valuable understanding. It points out a means of representing the flow through the use of barriers and value accelerators. Future development of the model needs to address:

- Sensitivity analysis of all parameter inputs.
- Validation of distributions used to simulate packet creation, barrier induced wait time, and probability of finding good packets.
- How cost information can be combined with the model to better analyze strategies for implementation of value accelerators (relevance to the business community).
- Looking at how value accelerators not only alter priority for faster movement through barriers, but may also generate new packets themselves (i.e., Brown Bag Lunches provide opportunities to exchange knowledge – but they may also stimulate new knowledge).
- Use of ANOVA to understand the statistical significance of treatments associated with employee population size, time, and other factors on:
    - average time for packets moving through the organization
    - average number of packets received per person per day.

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