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USE OF WIKIS AS AN ENGINEERING COLLABORATIVE TOOL

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ABSTRACT
This paper reports on the effectiveness of wikis for improving collaboration in engineering. Engineering has evolved from single-site design teams to non-collocated groups of experts with active involvement from every level of product stakeholder. Collaboration tools have been developed in order to accommodate these teams and integrate work on a single platform. Wikis are one such collaborative tool. Wikis are editable websites that allow users to add, delete and change any of the content that is on the site. For engineering collaboration, wikis can be tailored to facilitate a number of different roles like project management, knowledge dump and file storage. To examine the usefulness of wikis in engineering collaboration the authors analyzed the activity on a wiki that is part of a multi-university automotive research project. The project involves multi site, multidisciplinary collaboration on the design of an urban vehicle. By using the wiki, student participants are able to provide regular updates on the progress of their particular subsystems, allowing other team members to track changes that may affect their subsystems and take measures to adapt their design. From our observations the authors hope to determine how effective wikis are as a collaborative tool in engineering design and identify how the technology can be improved. By observing the wiki as it evolves through the design process, we can see if it retains its usefulness since each design stage brings new communication and collaborative needs. We will also compare wikis to conventional methods of collaborations and provide suggestions to improve wikis to make them more applicable to engineering collaboration.

Keywords: Computer-Supported Collaboration, design process, Wiki, early engineering design

1 INTRODUCTION

In the past, design teams have been limited to the personnel that were available within the immediate organizational and geographic area. They would have to rely on this expertise to carry them through the different aspects of the project. When there was a skill set lacking in the group they would hire external consultants to come to them because no sufficient distance/virtual technology existed.

Due to significant advances in communication technologies, companies no longer suffer this constraint. They can recruit the best available people even if they are half way across the world. However, this causes new complications, some of which are time zone differences that limit availability of personnel, differences in engineering standards and practices that can complicate component and system integration, and cultural differences that can hinder the communication between groups. Nonetheless, the quality and capability of the design group can improve greatly if these differences are overcome. Today, design teams not only have distant experts but they also have active involvement from every level of product stakeholder. All this has created a demand for collaborative tools that can accommodate these teams and integrate work on a single platform.

Before these tools were developed, non-collocated teams relied heavily on multiple forms of online communication like email and instant messenger, and file transfers which consumed a large amount of their local disk space and led to substantial duplication of information. This led to increased risk of losing documents, accidentally deleting important information, and lack of synchronization between the information stores and the participants. As a result, there arose a greater demand for more

computing resources, which incur ever-greater cost in both time and money. On the other hand, centralizing the project on one tool lowers the risk of information loss or error. Since most of these tools are web-based to facilitate far spread groups, any documentation can be stored on the single-server without having to download specialized software locally. The growing ubiquity of the Internet and the increased standardization of browser services also facilitate this.

Over the last decade, computer-supported collaborative work (CSCW) has become an ever growing field of research. CSCW looks at how collaborative activities can be supported by computer systems. Not only does CSCW develop tools that support the collaborative nature of work, but also explores the sociological and psychological aspects of work in order to understand how computer systems can compliment the collaboration. Although research in this area is very comprehensive, there has been little work related to the use of collaborative systems to assist engineers in the early stages of a product design process. While we continue to review the CSCW literature, we have found that relatively little has been done in the specifics of CSCW in engineering design.

2 WIKIS

A *wiki* is an open website where the audience can freely edit the content of the site. This creates a set of linked websites, which are incrementally developed by a group of collaborative users[1]. The concept of a wiki is to foster the input of the reader in order to further elaborate and refine the knowledge presented on the site. By allowing readers to edit the page more "experts" in that particular field can contribute their insight so that the community of readers can be better informed. Wikis can thus be thought of as a implementing a many-to-many knowledge creation model, as opposed to a one-to-many model, as in email or weblogs[2].

While this is a powerful tool for the collection of information, there is also a large potential for *misinformation*. There is no system in place to validate the information that someone may put on a wiki. A good example is *Wikipedia*. This encyclopedia wiki has rapidly become a resource for many people for quick information on various topics, but since the information in Wikipedia is provided by diverse users, there is no way of guaranteeing its accuracy [3].

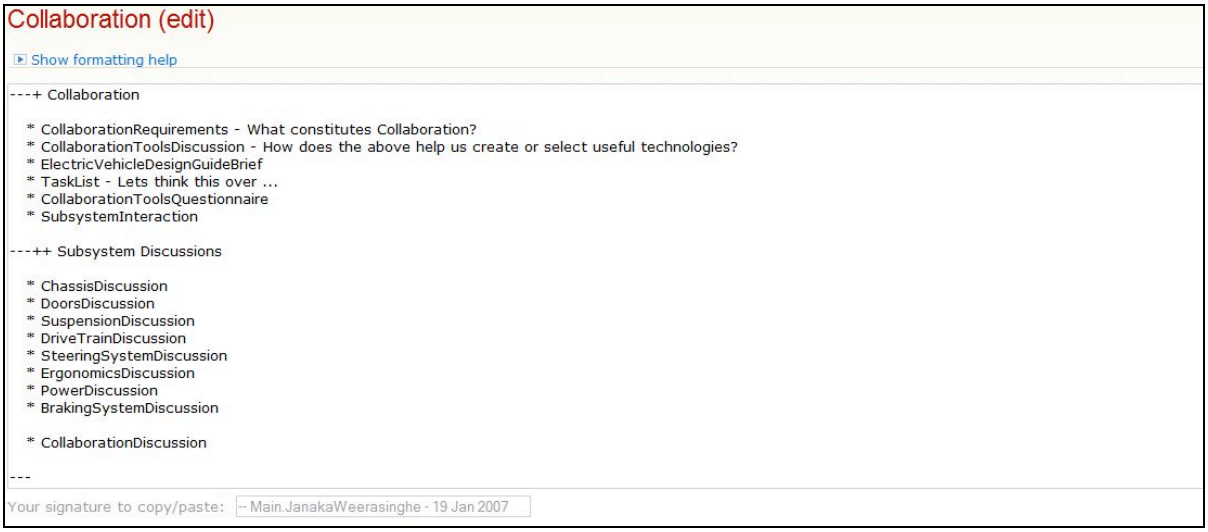


Figure 1. Example of a text editor

Wikis can be viewed with any Internet browser without having to download special software; this makes them highly accessible. Wikis fundamentally distinguish between *content* and *layout.* Content is to be provided by the wiki contributors, whereas layout is taken care of entirely by the wiki software. Wikis generally provide facilities to help contributors, including automatic version control, list of recent changes to wiki pages, etc. The major concept of the wiki is that it provides an open space for people to add information to the site without having to be proficient web programmers. Wikis allow users the ability to add, change, or delete any content. Most wikis also provide variable

security features, such as being able to limit edit privileges to only certain individuals or groups, and "hiding" key or private pages for general visitors to the site.

The text editor, as seen in Figure 1, comes with a special syntax, usually unique to each wiki, which is used to structure text with bullets, italics, bold lettering, headings etc. The following example shows the desired text and then the required editor text needed by the wiki to produce the desired text.

Desired text
Wikis are *very* **interesting.** A good example is Wikipedia.

Required text
Wikis are _very_ *interesting*. A good example is [[www.wikipedia.org] [Wikipedia]].

It is evident that there would need to be some period of learning before a user becomes comfortable enough to use the text editor consistently to edit wiki pages. Another hindrance is that different wikis implement different syntactic notations. Thus, users of one wiki may not be able to use other wikis easily. While there is ongoing effort to address this by developing standards for wiki syntax, no clear consensus has yet been reached.

To offset these problems, some of the more recent wikis have a WYSIWYG, What You See Is What You Get, option. The WYSIWYG is another text editor similar to a conventional word processor interface, as seen in Figure 2. This provides a more familiar interface for the average user so that one does not have to learn the text editor syntax. The premise here is that the editable space is an exact representation of what they page will look like, but usually this is not the case. There exist constructs used in many wikis for which there are no sensible WYSIWYG analogues. Rendering of the pages is also not perfect – there remain subtle but sometimes significant differences between the rendering in the WYSIWYG editor versus the final page. In TWiki (http://twiki.org), a wiki that is used in the project that will be discussed later on in this paper, the main page is laid out in colour, but the WYSIWYG space shows only black and white. Also many glyphs and icons that are included show up as plain text in the WYSIWYG and are only rendered properly once the page is saved.

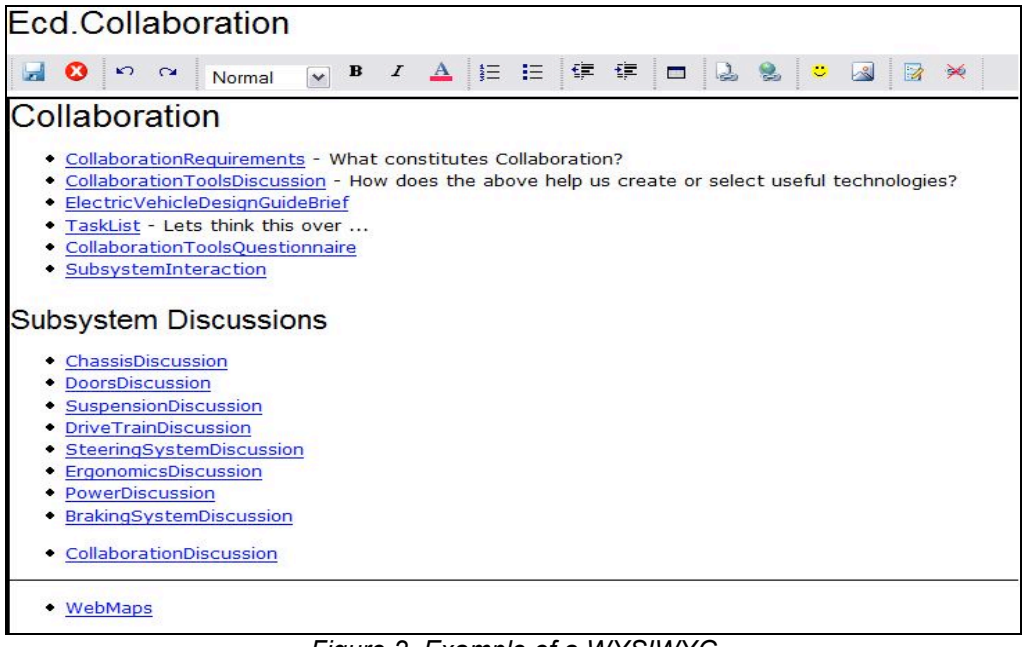


Figure 2. Example of a WYSIWYG

Nonetheless, using these tools provides a favourable platform for collaboration when compared to other approaches. By allowing users to freely add their own content it allows for the input from multiple experts on whatever the topic may be. This input enriches the knowledge being presented and makes it more valuable to outside readers. The wiki will keep track of all the changes made to

each page on the wiki, so if someone makes a change that others do not agree with then there is an option to revert the page to a previous version.

In order to protect the information stored in the wiki, administrators can restrict editing or even viewing privileges to only the members of particular projects. This way, only the members can change the information, and so provide some security on the validity of the content being presented. Furthermore, these security measures help identify who made what changes, since the wiki will keep a record of the changes and the users who made those changes. This increases user accountability.

Since many wikis are open source, there is no "capital" financial burden on companies to incorporate them. The burden comes in setting up the wiki as it can take some time to customize the wiki to perform the desired functions, and to train new users. Wikis can support many activities. The most popular of these is storing semi-organized information. Authors record information on the wiki as it becomes available so that others may view it and comment on it. Similarly, authors can upload supplementary documentation (such as images and documents in non-wiki formats) to the site. This makes it readily available to everyone that wants to view it without having to resort to email. Another popular aspect of wikis is the ability to support asynchronous discussion (as with email "mailing lists"). Some wikis, like *Wikispaces* (http://www.wikispaces.com) and Wikipedia, come with their own discussion sub-pages for each wiki page. This results in a forum style, where the discussion page would show a list of all the discussion threads that are organized by context [4]. Participants typically use conventions like horizontal lines or nested indentation to distinguish entries. Even if there is not a discussion option, the wiki is versatile enough that a page can be used as a discussion board with each thread having its own wiki page. For large projects, a wiki can be used as a project management tool since everything pertinent to the project is integrated on one platform. This makes it easier to track progress and identify tasks that are behind schedule. Some wikis, like TWiki, provide specialized "plug-ins" (like timelines and workflow packages) to support these activities. While the TWiki does provide these 'plug-ins', the fundamental operation of the wiki is simple so that the users can focus on the content of what they are trying to discuss and not have to worry about the tool they are using [5].

3 WIKIS IN ENGINEERING

The initial stages of an engineering design process consider the major product requirements, where the design team discusses the broad product characteristics, functional requirements, constraints, and performance metrics that the product must meet. This is done to narrow the focus of the designers to specific items when conceptualizing their solution. Wikis allow each designer to add their perspective on what the product should be made to accomplish, as well as any possible constraints that may not have been seen in the original design problem. With a wiki, all the characteristics, requirements, and constraints of the product can be clearly outlined on a wiki page for every member to see and discuss. As a project progresses through its life cycle stages, the cost of making changes to the design rises exponentially. Therefore, it is critical that the decisions made in the preliminary design phase be correct [6]. By using the wiki to centralize all the requirements, a design team will have all the critical information it needs to make the correct design decisions.

Engineers are always looking for the rationale behind design decisions, what other options the designers thought about, what they tried, and what mistakes they made in the past [7]. By providing all the research in one place as well as a record of all the discussions made, external consultants can clearly follow the team's thought process.

It is often the case that groups within a large team are given responsibility over specific product systems and subsystems. In order to have the overall product function properly, particular focus is placed on the interfaces between subsystems so that all the required inputs and outputs for each subsystem are accounted for. Especially in complex products, there can be many system interfaces. Here is where a wiki can be most useful. It centralizes all the information from each subsystem and allows group members the ability to readily see how their subsystem works in conjunction with all the other systems.

4 AUTO21

The "Automobile of the 21st Century" (hereunder, Auto21) is a Canadian Network of Centres of Excellence, a national research network intended to substantively advance automotive engineering in Canada. One of its many constituent projects is a multi-university endeavour aimed at exploring how engineers collaborate in the early stages of a design process. Graduate students from a number of universities across southern Ontario formed a team to design an environmentally friendly urban vehicle. Each student brought a different engineering expertise to the group allowing for an easier division of tasks making each school responsible for one sub system of the vehicle. The design of the car was just a medium to observe and analyze how collaboration was taking place within engineering design teams that were geographically separated. In order to study collaboration, the project members were introduced to a number of collaborative tools in an attempt to see what aspects of the tool were helpful in facilitating their collaboration. One of the tools was a wiki called TWiki (see Figure 3).

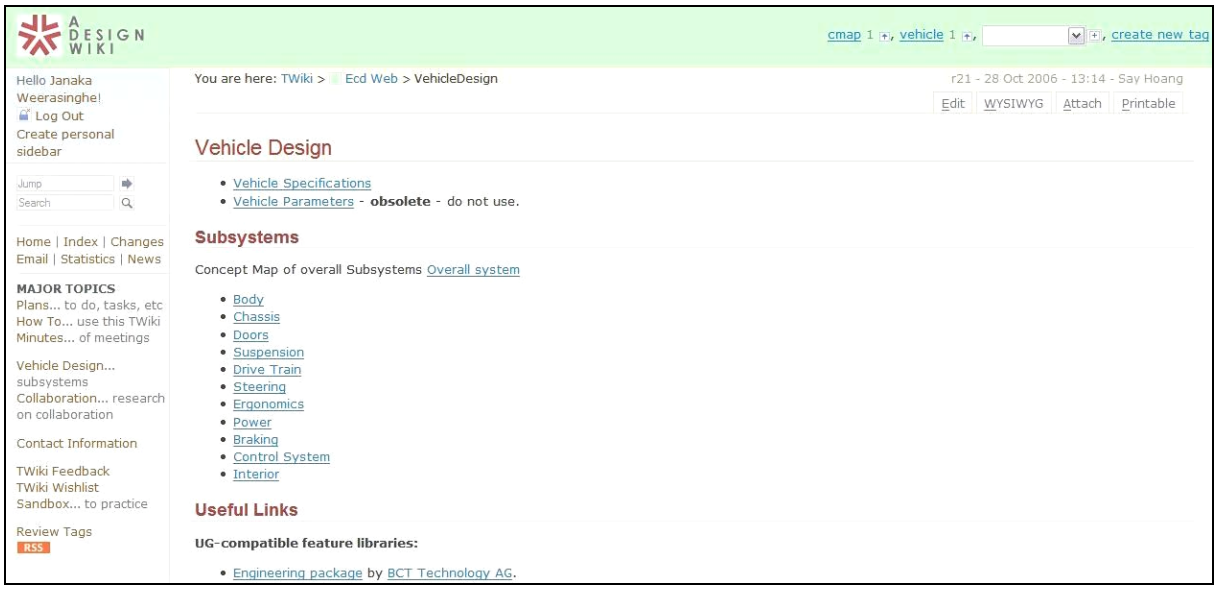


Figure 3. Partial capture of 'Vehicle Design' page from the Auto21 wiki

Ideally, the wiki would serve as a common place for the students to post all the research that they had conducted as it was gathered it. This would give other participants in the project the opportunity to review the work and see if it impacted the system that they were working on. It would also allow others to make suggestion or correct errors on someone else's work. Due to the versatility of the wiki, some of the pages are used as discussion forums where students are able to freely add comments on various topics so that informed design decisions can be made.

In order for the wiki to be effective as a collaborative tool, it has to inform the students as to when new information becomes available. For the TWiki wiki used in this Auto21 project, there is an option to get email notification on when some user has changed a page. Since wikis can get quite large, it would be inefficient and undesirable for users to be notified separately of *all* changes. With TWiki, the students have the option to request notification for *specific pages*. This way, users are only notified by email of changes that are pertinent to their specific interests. For instance, the group working on the urban vehicle's seats would likely be interested in changes to the chassis, but not interested in changes to the engine. These users would therefore subscribe for email notification of the wiki page dedicated to the chassis, but not to the page dedicated to the engine. These subscriptions can be changed easily by editing the appropriate entries in a specific TWiki page. TWiki also supports RSS feeds, which allow individual users to have their browsers automatically monitor specific web pages (TWiki pages, in this case) for changes. The browser then arranges a list of links to recently changed TWiki pages in chronological order. This is done purely from the user's browser and does not require any changes to TWiki pages. By using RSS feeds, a user can disconnect updates entirely from email; considering the large number of emails some users already receive, this is seen as a particular advantage.

5 EFFECTIVENESS OF WIKIS

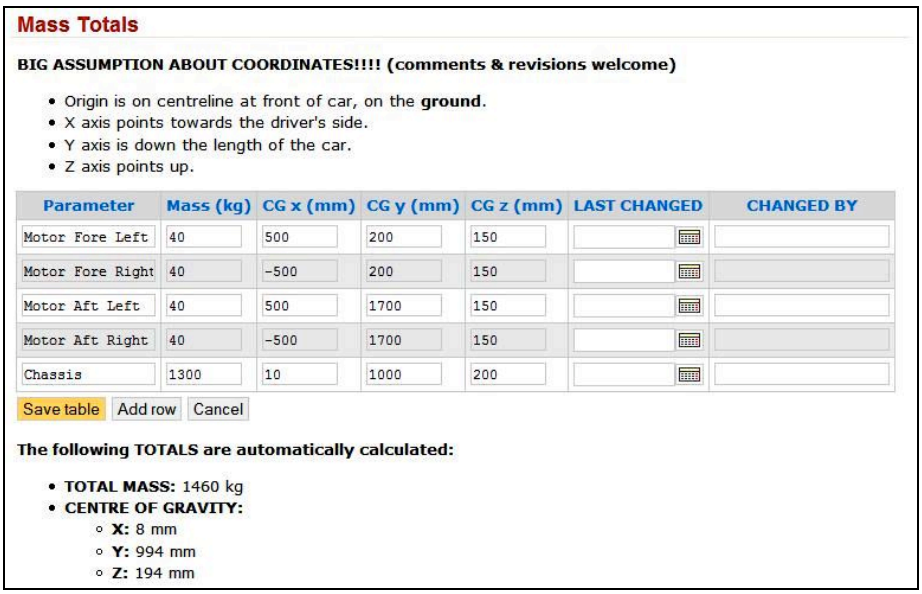
In the initial stages of the Auto21 project, the design team was introduced to a wiki called *OddMuse* (http://www.oddmuse.org). This simple wiki has only a text editor (no WYSIWYG function). We used it as a medium to start fostering discussion about the vehicle design project while TWiki was being set up. Exposure to OddMuse was also a first experience with wikis for many of the team members. The first few weeks of the project were a period of learning for these individuals as they became familiar with wiki syntax and rules for creating and editing wikipages. There was an immediate hesitance to use the wiki. Students felt that they had to put much more effort into their writing because they had to pay attention to the new formatting rules. Some felt wary of posting material that anyone could read – and possibly assess academically – even though it was made clear to them repeatedly that content provided on the wiki was a "learning experience" for everyone.

A great deal of preliminary information was put on the OddMuse wiki by team members that were trying to get familiar with the syntax, but as users became accustomed to it, they also started to notice that it was in some ways ineffective for their purposes. Thus, usage of OddMuse slowly waned. The three most common problems noted by users were: (1) inherent difficulty in performing certain highly desirable features like "inlining" images in OddMuse pages, (2) lack of a "natural-feeling" syntax for the text editor, and (3) an "unprofessional" look-and-feel of the site. These reasons discouraged several students participating in the project to post information and comment on existent information. As a result, many online discussions would suddenly become inactive. The most prolific contributors were the principal investigators (PIs), professors who already had experience with wikis and other collaborative tools, and so were more comfortable using them. The PIs also lacked the fear that their work was being assessed academically, and so were less likely to feel that someone was "looking over their shoulder" as they contributed. Students, who did most of the design work on the urban vehicle, worked largely off the wiki, using email and text messaging among smaller sub-groups, to coordinate their activities. Only the results of these collaborative efforts were posted to the OddMuse wiki. This deprived the authors of access to evidence of the actual collaborations that constituted the principal target of the project as a whole.

When the project was switched from OddMuse to TWiki (http://twiki.org), there was a noticeable change in usage. TWiki was visually more appealing than OddMuse and so students were much more inclined to explore the capabilities of TWiki. Even though the new wiki had a WYSIWYG that provided a more familiar interface on which to add new content there was used infrequently. Several functions (described below) were available in TWiki that were not available in OddMuse. The authors customized some TWiki functions to better suit the particular needs the Auto21 participants. The students found the new TWiki easier to work with and so were more inclined to use it and so there was a lot more activity thus greater productivity. Since TWiki was used more than OddMuse, but the WYSIWYG editor was *not* used, it seems that the peculiar nature of wiki syntax is especially important to engineering users compared to other functions and the general look-and-feel of the site.

TWiki includes a number of plug-ins that gives the users greater flexibility in storing, sharing, and visualizing information. One of the more useful plug-ins is an *editable table* as seen in Figure 4. This feature allows one to create a table of which certain cells can be edited without having to start a full edit session. The table was created and configured by the authors; this includes specifying row and column titles, which cells of the table are editable, what format each editable cell should use, and setting a few options, colours, etc. Once this was done, other authenticated users could update cells in the table directly. Unauthenticated users could only browse the tables, thus helping to keep the information secure.

Figure 4 shows part of the *Mass Totals* table, used to track the evolving overall mass of the urban vehicle, as well as the centre of gravity of the vehicle as a whole. Participants update rows in the table that correspond to major components for which they are responsible. The *Last Changed* and *Changed By* fields are automatically filled in when an authenticated user activates the editable table feature.



Mass Totals

BIG ASSUMPTION ABOUT COORDINATES!!!! (comments & revisions welcome)

- Origin is on centreline at front of car, on the **ground**.
- X axis points towards the driver's side.
- Y axis is down the length of the car.
- Z axis points up.

Parameter	Mass (kg)	CG x (mm)	CG y (mm)	CG z (mm)	LAST CHANGED	CHANGED BY
Motor Fore Left	40	500	200	150		
Motor Fore Right	40	-500	200	150		
Motor Aft Left	40	500	1700	150		
Motor Aft Right	40	-500	1700	150		
Chassis	1300	10	1000	200		

Save table | Add row | Cancel

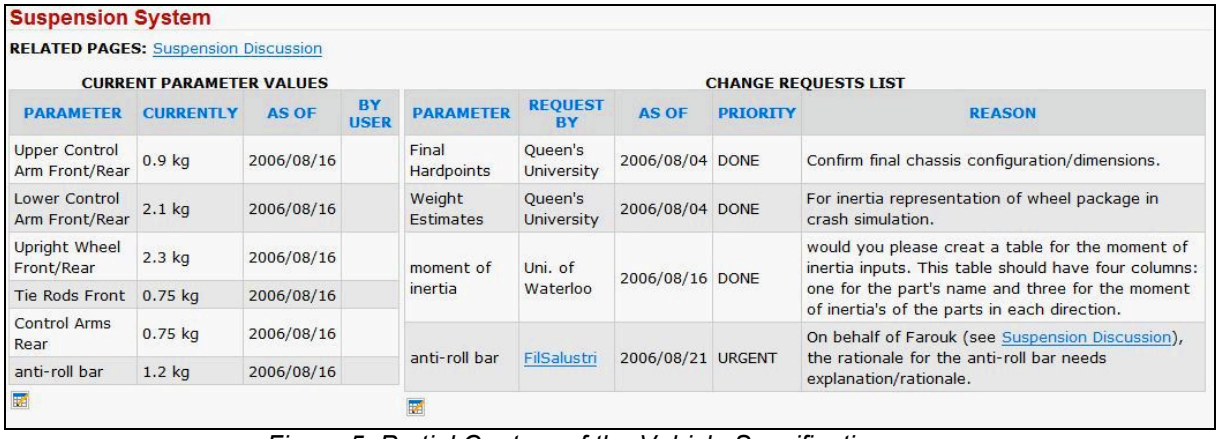
The following TOTALS are automatically calculated:

- **TOTAL MASS:** 1460 kg
- **CENTRE OF GRAVITY:**
  - **X:** 8 mm
  - **Y:** 994 mm
  - **Z:** 194 mm

Figure 4. Editable Table available on TWiki

In this way, other users can see who changed an item in the table, and when it was changed. These changes are also noted by both the email and RSS notification systems in TWiki. Thus, users subscribing to the change notification would simply receive a notice that the *Mass Totals* had changed. It would then be the user's choice to check the *Mass Totals* TWiki page to see the specific changes. Most importantly, we note the items at the bottom of Figure 4, below the editable table. These items automatically calculate the total mass and centre of gravity of the whole vehicle using data from the table contents. These values are recalculated each time a user saves a change to the table. While there are some limits on the complexity of the calculations that can be performed, the kinds of calculations needed in early design stages are usually quite simple. Because of this, the authors hope that the editable table feature will continue to be very useful to the design team.

Figure 5 shows two editable tables, side by side, rendered for typical browsing rather than for editing. The table on the left shows a partial list of design parameters for the suspension of the urban vehicle. The table on the right shows the current list of changes requested of the suspension group by other team members. By mutual agreement among all the team members, only members of the suspension group change the left table, but any stakeholder can request a change in the right-hand table.



Suspension System

RELATED PAGES: Suspension Discussion

CURRENT PARAMETER VALUES

PARAMETER	CURRENTLY	AS OF	BY USER
Upper Control Arm Front/Rear	0.9 kg	2006/08/16	
Lower Control Arm Front/Rear	2.1 kg	2006/08/16	
Upright Wheel Front/Rear	2.3 kg	2006/08/16	
Tie Rods Front	0.75 kg	2006/08/16	
Control Arms Rear	0.75 kg	2006/08/16	
anti-roll bar	1.2 kg	2006/08/16	

CHANGE REQUESTS LIST

PARAMETER	REQUEST BY	AS OF	PRIORITY	REASON
Final Hardpoints	Queen's University	2006/08/04	DONE	Confirm final chassis configuration/dimensions.
Weight Estimates	Queen's University	2006/08/04	DONE	For inertia representation of wheel package in crash simulation.
moment of inertia	Uni. of Waterloo	2006/08/16	DONE	would you please creat a table for the moment of inertia inputs. This table should have four columns: one for the part's name and three for the moment of inertia's of the parts in each direction.
anti-roll bar	FilSalustri	2006/08/21	URGENT	On behalf of Farouk (see Suspension Discussion), the rationale for the anti-roll bar needs explanation/rationale.

Figure 5. Partial Capture of the Vehicle Specification page

To start an edit session an authenticated user left-clicks on the small table icon at the bottom-left of each table. The icon has a "pop-up" indicating its purpose; this is especially useful to help new users of the TWiki. Once activated, the selected table is redrawn similar to the one shown in Figure 4. The TWiki contains tables like the ones shown in Figure 5 for every major system, as well as for the overall vehicle parameters. All these tables are grouped together on one *Vehicle Specifications* TWiki

page. This provides a central location where any team member can view all the essential parameters of the vehicle without going through each subsystem. Some participants had suggested having separate pages for each major system. After a lengthy discussion, however, all the students and PIs realized that such a separation would place much information "out of sight and out of mind;" that is, without being able to quickly scan the entire current specification of the vehicle, it was far more likely that important couplings between parameters, opportunities for refinements, and specification inconsistencies would be missed. The authors, who tried to facilitate the discussion without biasing it, agreed with this assessment: the *Vehicle Specification* page provides a holistic overview that would be lost if it were broken into per-system sub-pages. These tables give a sense of group awareness to the participant, which is important for a collaborative environment. Group awareness knowledge includes who is working on the project, what they are working on and what they work they are planning on doing [8]. This improves coordination and communication between the groups.

Another very useful tool in TWiki is the *Comment Box* (see Figure 6). Ordinarily, a user wishing to post a comment to a TWiki page would have to register for edit privileges, then start a regular edit session, find and appropriate spot in the page, add the comment, and then save the changes. For short comments, this process can be quite tedious. The *Comment Box* provides a much faster and easier alternative, by letting any user – even unauthenticated users – to post a short comment. This particular operation does not necessarily require user authentication because TWiki itself adds the comment, and the user submitting the comment cannot change or delete any other page content. TWiki inserts the comment immediately above the comment box itself. If the user submitting a comment is authenticated, the comment is automatically "signed" with the user's name, which helps ensure proper attribution of content. Every comment is automatically time stamped by the system.

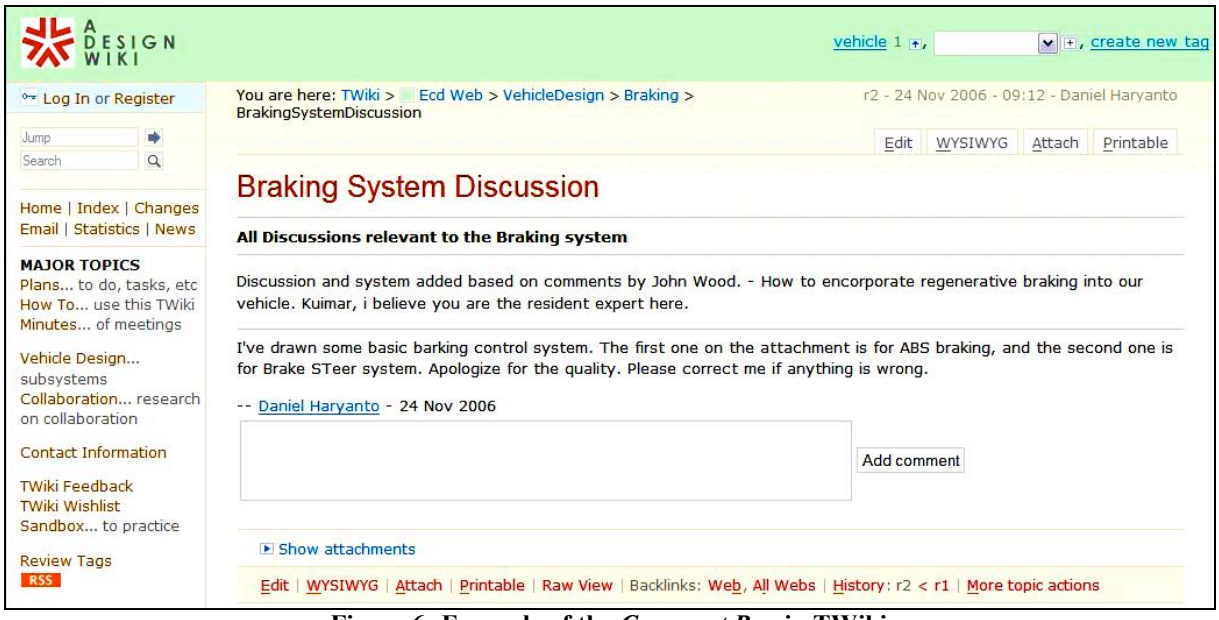


Figure 6: Example of the *Comment Box* in TWiki

The *Comment Box* feature was especially welcome by students who exchanged a variety of questions, answers, and comments about the vehicle design tasks. In some cases, users added comments so rapidly that the system began to take on the appearance of an instant messaging system rather than a conventional wiki. All users noted this feature in particular as one of the most significant improvements over the original OddMuse wiki. As the project progressed from a preliminary design phase, where the focus was on defining the problem, to a detailed design phase, where there was much more part design, the team began using CAD and analysis software more, and the wiki was used less. Some students were now creating complex CAD models for their specific subsystem so that they could perform stress tests. Others were generating simulation software to test the feasibility of the suspension design. The students found that the wiki was not suited for collaboration at this phase due to the complex nature of these analyses and software. They would still use the wiki as a way to show their results, but only when they completed specific tasks. While actively working on their systems,

they would still collaborate with the other members of the design team, but they would revert back to familiar tools such as emails and instant messaging services. Collaboration would occur between two individuals where CAD files or simulation code would be sent through email and then if there was any discussion on how to improve the models they would use an instant messaging service like MSN to communicate. While this is still a powerful method of communicating and collaborating, there is no record of these events since posting emails and message histories is inefficient. So while the wiki is useful in the early stages of a product design, it seems like its applicability for active collaboration diminishes as the project moves to latter stages as it requires synchronous or near synchronous communication for some aspects [9]. The goal of the project was to study the impact of wiki usage on collaborative designing. However, the project has run into certain difficulties. Most significantly, TWiki usage dropped significantly. It is not clear yet why this is so. Possible explanations include:

- Certain key students and PIs who were "champions" of collaborative tools like TWiki have left the project. Without these champions to keep pressure on the rest of the team, "old habits" (using email, conventional text messaging, etc.) have been revived.
- The flat organizational structure implied in wiki collaborations runs counter to the conventional deep hierarchies of North American engineering practice with which most PIs and graduate students are already accustomed. The resulting discomfort with not having a clear "boss" assigning strictly defined work packages is pushing people away from the wiki.
- The project is awaiting news of continued funding beyond April 2007. It may be that some participants are unwilling to invest time in a project that may be near its end.
- Students may be too focused on completing thesis work – a solitary undertaking by definition.
- Other, as yet unidentified causes.

The authors continue to monitor the project closely, to see what other data may be extracted. We are also reviewing the literature on collaboration and its facilitation to see what other symptoms may be pertinent. We remain hopeful that we will be able to address this situation. We have also started to track TWiki usage more closely, taking "snapshots" of the state of the wiki at regular intervals, in the hope of identifying trends that could help explain the team's behaviour. After a number of significant changes have been made to a particular page a screen capture is taken using *Scrapbook* (a Firefox browser extension). Scrapbook allows a user to capture and save any part of the page in any of format that the browser uses so that it may be viewed independently of the original. This is more effective than bookmarking as it captures the state of the page on that particular occasion without having to save a copy to the hard disk. Scrapbook also allows the user to make notes on each of the captures by providing tools like *Highlighter* to indicate particulars areas of interest on each page, or *Pencil* to create virtual sticky notes onto the page. It also has a *Comment* option where additional information can be attached with the page to indicate the reason for making the capture. The layout of Scrapbook is similar to the bookmarks in that files can be organized into folders. This tool is particularly helpful for this project as it allows us to see how the wiki is being used throughout the project. By taking captures of the same subsystem page we can see the progression of work being done on that particular subsystem to see if there are any patterns to the way the students collaborate.

6 CONCLUSION

Even though this project has provided some insight into the collaborative nature of wikis, there are still limitations to its application to engineering design. The authors' goal is to study the usefulness of wikis to the preliminary engineering design phase of a product lifecycle. Although wikis exist specifically to promote collaboration, and continue to increase in popularity in other settings, adoption of the wiki technology for this project has been sluggish. This does not seem to be due to inherent shortcomings of the particular wiki that we are using in this project; all participants have indicated satisfaction with the functionality of the TWiki. The concept of a wiki seems generally viewed as appropriate to team-based collaborative designing. Initial findings show that the participants of the project were able to outline the basis of the project and thus create an organized environment from which to advance their design. The use of the editable tables provided unique form of collaboration as it allowed the users to see the current state of affairs on one side and the discussion of those criteria on the other side. As a result, there was much more activity on these pages than on traditional forum

style discussions. The authors hope that with further analysis and research over the next six months, we will be able to make a better determination as to the contribution of wiki collaboration to early engineering design. The results of this work will drive subsequent work in establishing methods and new tools to promote collaboration.

REFERENCES

[1] Leuf, B. and Cunningham, W. 2001. *The Wiki Way: Quick Collaboration on the Web*. Addison-Wesley.

[2] Wagner, C. 2004. Wiki:A Technology for Conversational Knowledge Management and Group Collaboration. *Communications of the Association for Information Systems*. 13:265-289.

[3] Goodin, D. 2005. Wikipedia as Accurate as Encyclopedia Brittanica: Science Journal. *Globeandmail.com Technology*. [URL: http://www.theglobeandmail.com/servlet/story/RTGAM.20051215.gtwikidec15/BNStory/Technology]. Accessed 2007/1/20.

[4] Louridas, P. 2006. Using Wikis in Software Development. *IEEE Software*, IEEE, 23(2):88-91.

[5] Yankelovich, N., Walker, W., Roberts, P., Wessler, M., Kaplan, J., and Provino, J. 2004. Meeting central: making distributed meetings more effective. *Proceedings of the 2004 ACM conference on Computer Supported Cooperative Work*. pp. 419-428.

[6] Hyman, B. 2003. *Fundamentals of Engineering Design, 2nd ed*. Pearson Education Inc.

[7] Hatamara, Y. (ed). 2006. *Decision-Making in Engineering Design*, 2006. Springer-Verlag, London.

[8] Gutwin, C., Penner, R. and Schnieder, K. 2004. Group Awareness in Distributed Software Development. *Proceedings of the 2004 ACM conference on Computer Supported Cooperative Work*. pp 72-81.

[9] Raygan, R. and Green, D. 2002. Internet Collaboration: TWiki. *Proc. IEEE SoutheastCon*. pp. 137-141.

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