

## **ANALYSING PRODUCT DEVELOPMENT WORKING PRACTICES FOR ENHANCING INNOVATION THROUGH COLLABORATION AND SIMULATION**

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*Keywords: innovation management techniques, design and manufacturing knowledge, as-is model, to-be model, creativity*

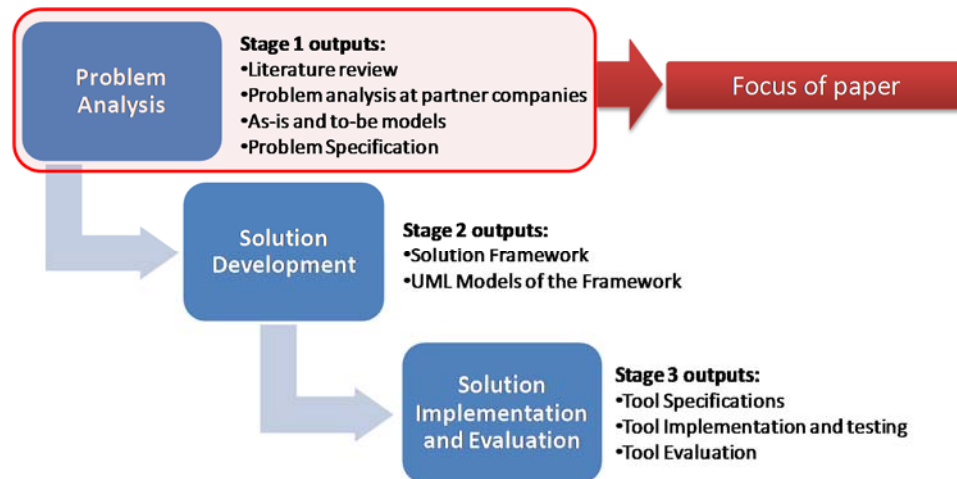
### **1. Introduction**

The importance of innovation for success in the 21st century economy is evident from the numerous articles on innovation that begin with the statement “companies must innovate or they will die”. It is not sufficient anymore for companies to compete on the basis of cost or time-to-market – if innovation is not part of the company culture, it is very difficult to survive in today’s fast-paced and competitive market. Furthermore, as stated by [Adams et al. 2006], companies seeking to be innovative should establish formal processes for innovating and make use of tools that facilitate innovative endeavours. The importance of tools as an input to the innovation process is also highlighted by [Cooper et al. 2004]. These tools fall under various categories such as tools for promoting creativity and tools for quality control [Adams et al. 2006]. This research argues that for the innovation process to be successful, two activities together with their supporting tools are required – stakeholder collaboration and artefact simulation. *Stakeholder collaboration* here refers to collaboration between product development stakeholders, such as designers, customers and manufacturing engineers, required to develop innovative products. *Artefact simulation* refers to simulation of both the product being developed as well as the manufacturing processes and systems used to develop the product.

Both activities fall within what is termed in this research as the *Innovation Cloud*. Within this cloud is the product development process that involves multiple experts (e.g. designers, production managers) coming from different areas and who need to *collaborate* together to develop innovative products and manufacturing systems [Adams et al. 2006], [SDRC 2000]. The innovation process is preferably assisted by means of *Innovation Management Techniques (IMTs)*, which are a range of techniques that help companies adapt to different circumstances and market needs in a systematic way [Phaal et al. 2006]. However, collaboration and IMTs by themselves are not sufficient. One of the main stumbling blocks when it comes to the implementation of innovative ideas is the justification of new capital expenses in the short-term and the prediction of long-term profits and other performance metrics such as assembly time, environmental impacts, etc. Thus, *artefact simulation* is required to predict the consequences of the innovative ideas generated and compare their feasibility from a performance metric perspective [Westkämper 2007]. In view of these arguments, the ultimate goal of this research project is to develop a framework through which product development stakeholders are able to enhance innovation in the product and its manufacturing process, by the use of innovation tools as well as collaboration and simulation tools. In this paper, the focus is on the problem analysis phase of the research project, more specifically on the data collection carried out at local manufacturing companies and on the generation of as-is and to-be models (Figure 1).

The rest of the paper is structured as follows: Section 2 gives a review of previous work carried out in this research area. In Section 3, the research questions that need to be addressed by this research are

specified. Section 4 describes the data collection method, that has been utilised to collect data from the five project partner companies, in order to answer the research questions. In Section 5, the results obtained are described and analysis of the current design working practices for enhancing innovation through stakeholder collaboration and artefact simulation is carried out. Section 6 qualitatively discusses these results and prescribes three to-be models for enhancing innovation – the innovation, collaboration and simulation to-be models. Paper conclusions are then drawn in Section 7.



**Figure 1. Phases of the research project and focus of this paper**

## 2. Literature review

Although research has been carried out on the topics of innovation, collaboration and simulation, these have not, to date, been considered collectively. For example, considerable work has been carried out on the creation of different tools that directly support innovation (e.g. SCAMPER, Brainstorming, etc.) but this work is independent of the use of other collaboration and simulation technologies. [Achiche and Appio 2010] describe a number of tools that are used to support the very early stages of the innovation process and prescribe a decision support tool to be used by product development stakeholders in these front-end activities. However, no mention is made to stakeholder collaboration or artefact simulation, both of which are important activities for the innovation process.

From a literature review carried out on state-of the art technologies supporting artefact simulation, it was found that there are a number of simulation tools, both in commercial use and in the research phases, that support various artefact life-cycle stages e.g. FEA, Mould Flow Analysis. However, it was concluded that none of the tools reviewed contributes directly towards enhancing or supporting innovation in a product development scenario. For example, Finite Element Analysis (FEA) tools are used to simulate problems of structural and dynamic nature in artefacts however they do not directly assist the user to be more innovative in solving these problems.

A literature review has also been carried out on state-of the art technologies supporting stakeholder collaboration, many of which are also commercialised e.g. videoconferencing, desktop sharing, etc. Some of these support synchronous collaboration (e.g. videoconferencing), others support asynchronous collaboration (e.g. email) while others support both (e.g. wikis). A small number of collaboration technologies also incorporate an innovation perspective by employing one or more innovation tools. For example, FacilitatePro Web meeting software [Facilitate.com 2011] aims to assist meeting participants unleash their creativity and converge towards an ideal solution by incorporating brainstorming and idea prioritisation tools in a web-based environment. [Kobayashi et al. 2007] propose a support system which aims to analyse designers' ideas during collaborative design sessions using Data Envelopment Analysis (DEA) and assists in visualising the communication taking place among designers with the ultimate goal of increasing the designers' creativity. However, as also

stated by [Kobayashi et al. 2007], currently “there are few researches that focus on the creative side of collaboration and support designers’ creativity”.

This research aims to address this research gap by collectively considering innovation, collaboration and simulation support tools. This is performed through research on product development stakeholders’ awareness of these tools and if this needs to be increased. It is after being aware of the benefits of these tools that product development stakeholders can be encouraged to use them in practice with the ultimate aim of enhancing innovation in the product development process.

### 3. Research questions

In the initial stages of this research, a set of research questions that need to be addressed were formulated. To answer these questions, a problem analysis was carried out in the five project partner companies (refer to Table 1). This helped the researchers understand the current working practice in these companies when it comes to innovation in product development as well as think of ways how this can be enhanced. The research questions (RQs) are the following:

- RQ1. To what extent is innovation during product development activities considered important?
- RQ2. To what extent are product development stakeholders aware of existing innovation tools? Do they use these tools during product development activities?
- RQ3. How important are stakeholder collaboration and artefact simulation to enhance innovation?
- RQ4. To what extent are product development stakeholders aware of existing collaboration and simulation tools? Is there anything that inhibits them from using these tools?
- RQ5. Do product development stakeholders need more awareness of existing innovation, collaboration and simulation tools? If yes, how can this awareness be amplified to enhance innovation in product development activities?

**Table 1. Company background information**

Company Name	No. of participants	Domain
Techniplast Ltd.	1	Plastic products for the food packing industry, pharmaceutical industry, etc.
Toly Malta Ltd.	1	Plastic packaging components to the cosmetic, fragrance and skin care industries
FXB Group	3	Furniture, wooden apertures and renewable energy products
Playmobil Malta Ltd.	2	Playmobil Toys– plastic figures and accessories
Rayair Automation Ltd.	1	Design and Manufacture of automation machinery

### 4. Data collection

For the problem analysis in this research, semi-structured interviews have been carried out in each of the five project partner companies. Hence, evaluators were asked a pre-defined set of questions but they were also free to add any other comments they felt appropriate. This helped in the generation of qualitative results. To appropriately design the questionnaire used in the interviews, the basic process outlined by [Burgess 2001] has been adopted. The process consisted of the following steps:

1. Definition of the research aims: The aim of the problem analysis was mainly to answer the research questions outlined in the previous section.
2. Identification of the sample to be used: As sample, a person from each company who was knowledgeable enough to be able to provide answers to all the research questions was selected. This was generally either the company’s Chief Operations Officer or the Managing Director. In certain cases, several persons representing different sections of the company attended the interview (refer to Table 1).

3. Decision on how to collect replies: To set up appointments with the interviewees, emails and follow-up phone-calls were used. In addition, to ensure that the right person from each company was interviewed, the research aims were briefly described in each case.
4. Design of the questionnaire: Questionnaire design involved determining the questions to be asked, selection of the wording for each question and finally setting up the the overall question layout. The questionnaire was divided into the three main parts of the research focus, namely Innovation, Collaboration and Simulation in Product Development.
5. Carrying out the main survey: During the interviews, a brief overview of each section of the questionnaire was provided to ensure that the terminology used throughout was understood. Moreover, the interviewees were encouraged to add any comments they felt appropriate. Permission for tape-recording, required for future data analysis was also granted in each case.
6. Analysis of the data: A preliminary analysis of the data collected was then carried out as discussed in the next section.

## 5. Results and data analysis

With reference to RQ1, all the interviewees stated that they considered innovation as being important for their company. This was further highlighted by the statements made concerning innovation in product development, such as *“it is very important”*, *“innovation is the continuation of success”* and *“for our company it is critical”*.

When asked whether they are aware of any innovation tools (RQ2), only two of the interviewees mentioned actual innovation tools, namely brainstorming and thinking tools [De Bono, 1990]. For others innovation tools included instruments e.g. measuring instruments, private thinking and the internet. One of the interviewees also stated that to innovate, no particular tools are used - *“it is not really a particular tool but more a question of keeping ourselves informed”* and mentioned collaborations with university and customer visits as means to capture new ideas and get inspirations. Only in one of the companies is the workforce formally trained in creative thinking.

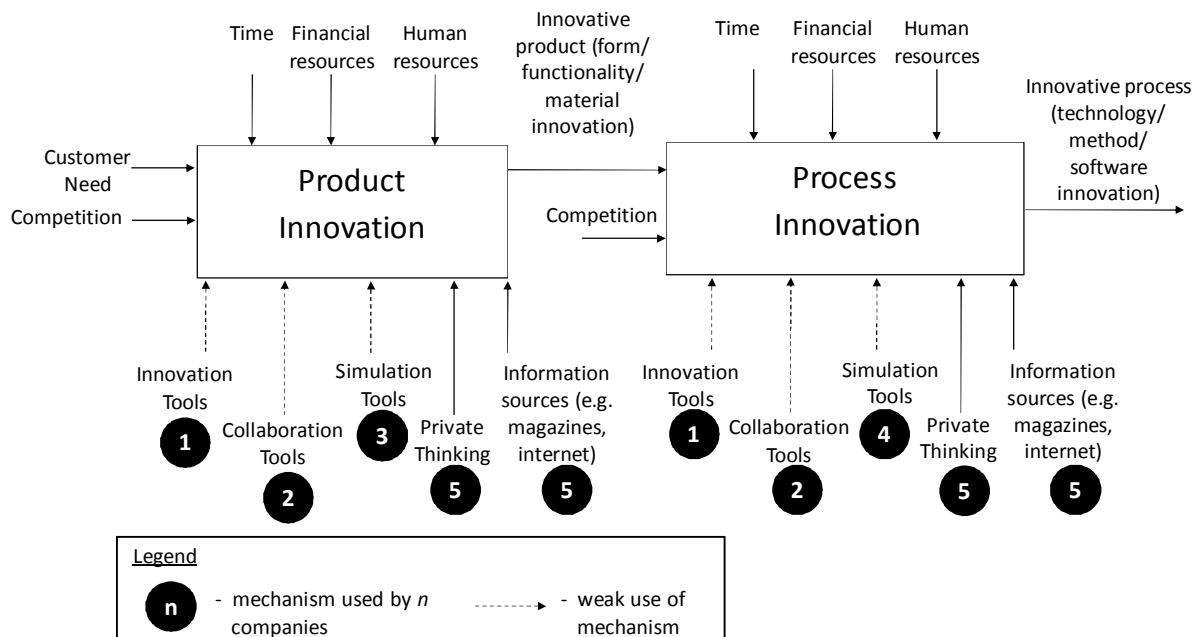
With reference to RQ3, all the interviewees agreed that collaboration is an important means for enhancing innovation. Some statements made include *“without collaboration it’s very hard to increase innovation, if not impossible”* and *“there is no other way – it is very important”*. External collaboration (both with companies in the same sector and in different sectors) is considered an important contributor in this respect because one can get external insights which are not present in the stand-alone company. Furthermore, 80% of the evaluators stated that the more ideas available, through collaboration, the more likely is innovation. Statements made include *“one idea leads to another”* and *“everyone has something to give”*. Four out of five interviewees agreed that simulation also helps increase innovation, mainly due to the visualisation achieved with these technologies. The other interviewee stated that he does not have enough knowledge of simulation to be able to answer this question. The main area of innovation that can be enhanced that was mentioned in this case was innovation in manufacturing process development because, through simulation, one can notice problems upfront and would be able to get the solution right the first time.

When asked whether they are aware of any collaboration tools (RQ4), the tools mentioned included mainly communication tools such as videoconferencing, emails, phone and face-to-face meetings. Other tools mentioned were engineering forums and desktop sharing software (such as Webex). Tools that are actually being used in the companies for collaboration include face-to-face meetings, email, phone, instant messaging and videoconferencing. In particular, face-to-face meetings, email and phone were mentioned by all the interviewees. The main inhibitors to using other existing collaboration tools that were mentioned include lack of awareness, lack of necessity and the felt need for face-to-face meetings (especially for communication with the customer).

With reference to artefact simulation, it found that all the companies use CAD software and are aware of the 3D virtual simulation capabilities of this type of software. Most of the companies are also aware of some manufacturing process simulation tools, in particular mould flow simulation and some mentioned also machining process simulation. However, although all the companies carry out 3D virtual simulation of their products, only three companies mentioned the use of manufacturing process simulation. The main reason mentioned as a detriment to the take-up of simulation technologies was

their return on investment. Most simulation tools are very costly to implement and their return is not enough to justify their expense in the eyes of the partner companies. Thus, companies tend to use simulation software on a sub-contracting level and only upon request.

From the results obtained for RQ2 and RQ4, three generic as-is models on the current use of innovation, collaboration and simulation tools were generated. IDEF0, which illustrates the functions and activities of the subject area, has been selected as the modelling technique. This technique provides for better understanding and supports analysis as well as provides logic for potential changes. The as-is innovation model (Figure 2) shows two innovation functions which are common to all the companies, namely *product innovation*, or innovation in the manufactured product itself and *process innovation*, which includes innovation in the process, tooling and equipment used to manufacture the product. These functions are represented using function boxes of an IDEF0 diagram.



**Figure 2. As-is innovation IDEF0 model**

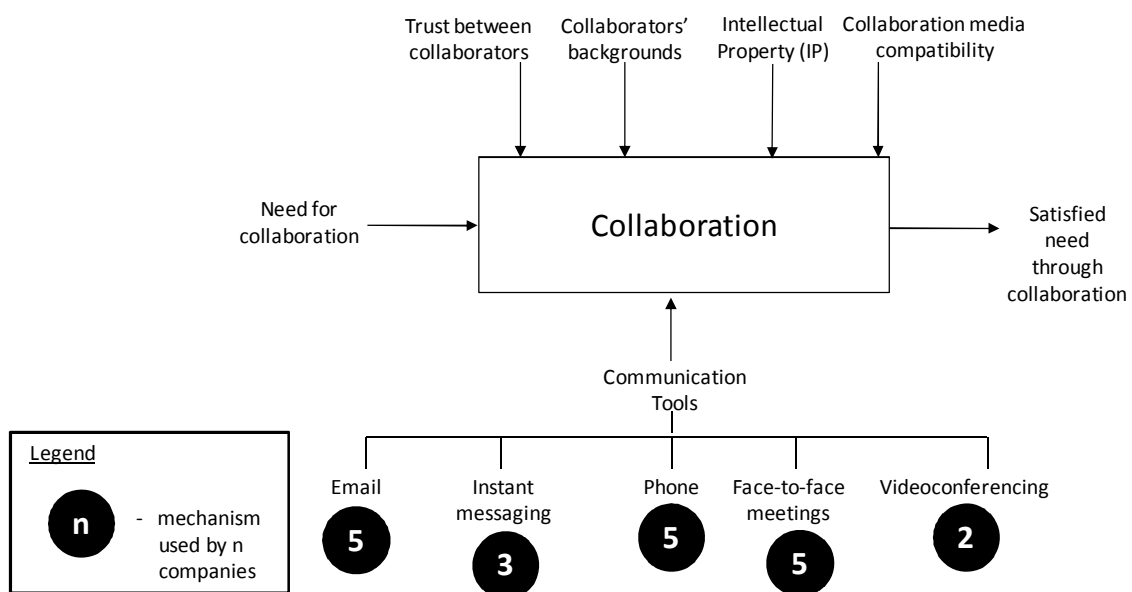
Inputs to product innovation which are common to the companies include *customer need* and *competition* and the output is the *innovative product*. Thus, product innovation is driven either by the customers, who increasingly require lower product cost, increased product functionality, etc. or else by competition, that is, by other companies which put pressure on the company to be innovative in order to keep its market share. On the other hand the output, that is, the innovative product, can include innovation in the product form, its functionality or its material amongst others. Inputs to process innovation include the *innovative product* and *competition*. Competition in this case is mainly in terms of cost, that is, the company tries to be innovative in the process to reduce the cost of manufacturing its products so that it remains competitive. Innovative products are also inputs to process innovation because if the product is different, new technologies and processes may be required. The output of process innovation, the *innovative process*, can be in terms of technology innovation (e.g. new tools, equipment, etc.), method innovation or software innovation.

Both product and process innovation are controlled by *financial and human resources* as well as *time* – that is, the available time-to-market. Although inputs, outputs and controls of product and process innovation are common to the companies, the tools used to innovate vary between the companies as discussed earlier and as illustrated in Figure 2. The tools that were mentioned by all the companies were *information sources* e.g. internet and *private thinking* by the company employees.

In the as-is collaboration IDEF0 model (Figure 3), the central function is *collaboration*, with the input being the *need for collaboration* and the output being the *satisfied need through collaboration*. Based on the evaluation results, the controls, which are common to the companies include:

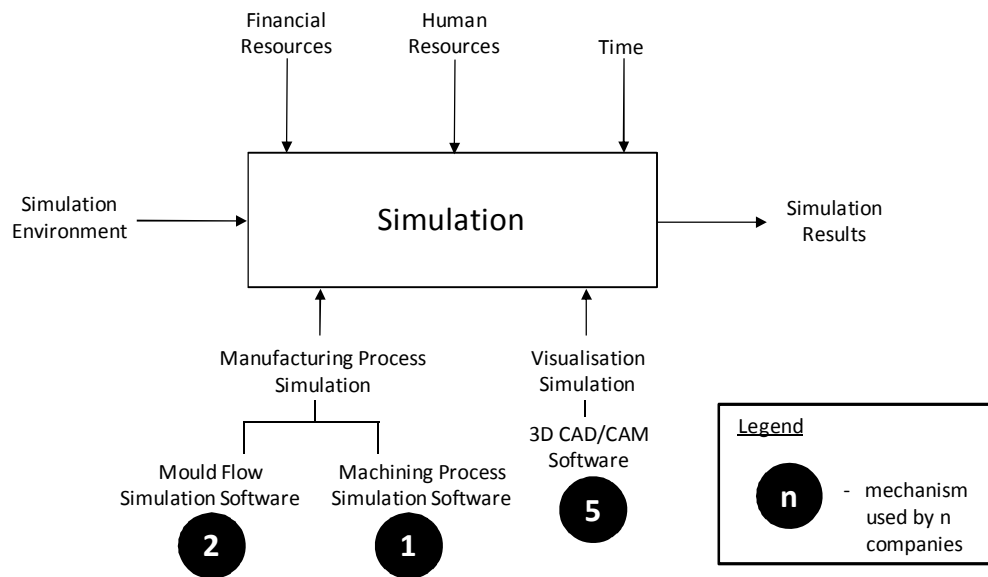
- *Trust between collaborators*: Trust is deemed as an important prerequisite for collaboration to take place effectively;
- *Collaborators' background*: The collaborators' background also affects the collaboration taking place. For example, one of the evaluators mentioned that due to background differences, engineering and marketing people tend to find collaboration difficulties;
- *Intellectual property*: Intellectual property is also an issue which tends to limit collaboration, especially external from the company;
- *Collaboration media compatibility*: Collaboration media used must be compatible for collaboration to take place effectively. For example, if the collaboration software (e.g. instant messaging or videoconferencing software) used between collaborators is not compatible, collaboration cannot take place.

Although inputs, outputs and controls of collaboration are common to the companies, the tools used vary as discussed earlier and as illustrated in Figure 3. However, the tools mentioned all fall under the category of *communication tools* [Munkvold 2003]. The tools that were mentioned by all the interviewees were *face-to-face meetings, email and phone*.



**Figure 3. As-is collaboration IDEF0 model**

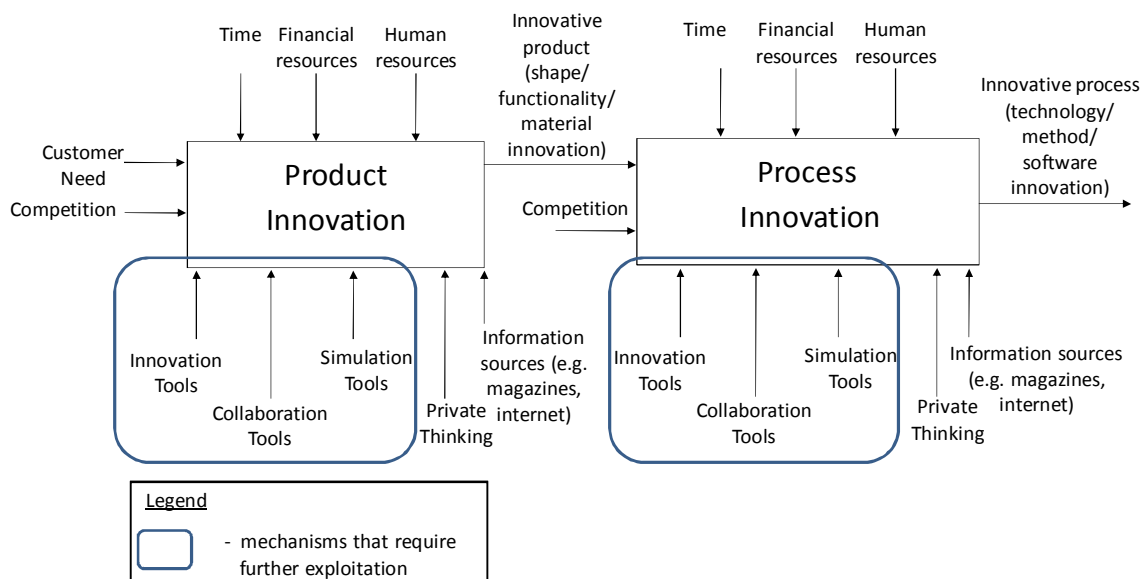
Figure 4 shows the as-is simulation IDEF0 model. The central function is *simulation*, which can be either product or manufacturing process/system simulation. The function input is the *simulation environment* and the outputs are the *simulation results* e.g. to carry out some improvements on the mould, such as relocation of injection point, or cooling and filling parameters. The controls, which are common to the companies include *financial and human resources* as well as *time* – that is, the available time-to-market. From the evaluation results, it emerged that the simulation tools used vary between companies as illustrated in Figure 4. All the companies were found to use *3D CAD/CAM software* to visualise the products being developed and identify any interferences between subassemblies. Two companies make use of *Mould Flow simulation* during the development of their moulds. However, in reality this use is limited as they rely heavily on the experience of their designers and simulation is only used when it is explicitly requested by the customer. Some interviewees also mentioned that they did not see the expected return on investment from simulation and thus preferred to rely on the experience of their designers. Only one of the evaluators mentioned the use of other simulation software, namely *Machining Process simulation* software, which in this case is used to simulate tool cutting paths in order to optimise the machining process.



**Figure 4. As-is simulation IDEF0 model**

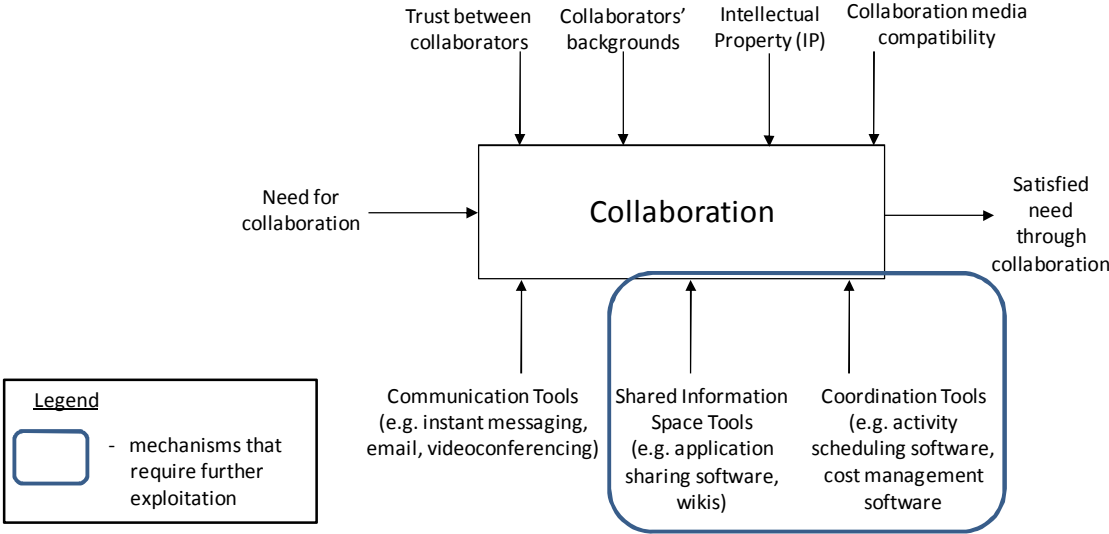
## 6. Discussion

From the as-is innovation model, it is observed that the main innovation mechanisms currently in use at the partner companies include information sources (e.g. magazines, internet) and private thinking. Although these clearly contribute towards the creation of innovative products and processes, there are other mechanisms such as *innovation tools*, *collaboration tools* and *simulation tools* which are currently not being fully exploited to further increase innovation. For example, although brainstorming sessions are often held during meetings, the thinking carried out during these sessions is generally unstructured. Thus, what is proposed in the to-be innovation model is that innovation tools (e.g. Concept Maps, SWOT Analysis, etc.) are used during these sessions to structure the thinking and hence increase the chances of innovative ideas being generated. In addition, although both collaboration and simulation emerged as important means to increase innovation, it has been found that the use of collaboration and simulation tools is still lacking in the partner companies. The to-be innovation IDEF0 model is illustrated in Figure 5.



**Figure 5. To-be innovation IDEF0 model**

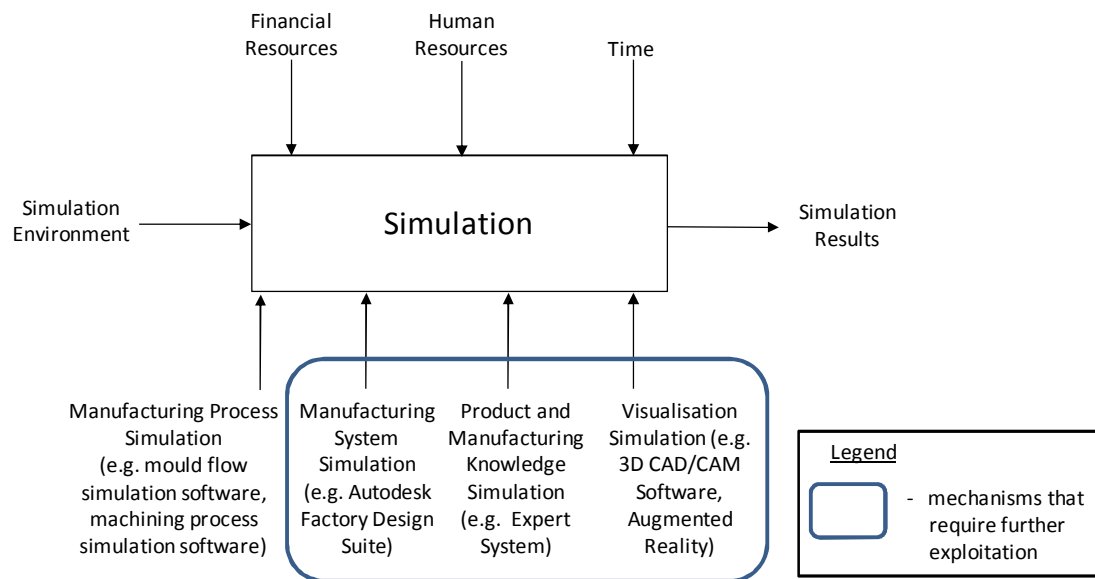
From the as-is collaboration model, it is observed that the main collaboration mechanisms currently in use at the partner companies are *communication tools* (such as phone, instant messaging and videoconferencing) with *coordination* and *shared information space tools* being visibly lacking. Although communication tools can provide for both synchronous and asynchronous interpersonal communication, they do not provide information storage and processing functionalities. Thus, reference to innovative ideas that have been generated becomes difficult. On the other hand, shared information space technologies support collaborative work related to the creation and handling of information objects such as documents, drawings, etc. and to the creation of virtual interaction spaces such as discussion lists [Munkvold 2003]. Examples of shared information space technologies include application sharing software and wikis, which not only support communication but also provide facilities for information processing. Coordination tools include technologies for cost management and activity scheduling amongst others [Wang et al. 2002]. Examples include workflow management systems and online calendars, which facilitate coordination activities. The to-be collaboration IDEF0 model is illustrated in Figure 6.



**Figure 6. To-be collaboration IDEF0 model**

As regards to the simulation aspect, it is observed that although all the partners use CAD Systems to develop and virtually simulate their products, no dedicated CAD system is being used to *visualise* the manufacturing system being developed or operated. Thus, during manufacturing system design, innovative ideas cannot be easily developed and communicated to other product development stakeholders. Also, the visualisation of products being developed is limited to visualisation on a computer screen or on paper. Other technologies exist, which the partner companies are currently not aware of, which improve the visualisation of the artefact being developed, such as the emerging technology of Augmented Reality. From the investigation carried out, it was also discovered that whilst limited use is made of *manufacturing process simulation* technologies (e.g. mould flow analysis), none of the partner companies is currently aware, or makes use of, *manufacturing system simulation*. The suites of simulation software in this field provide support through different functions. The 3D virtual model is used to navigate through the virtual factory and identify any problems and develop solutions even before the factory walls have been erected. This helps engineers carry out manufacturing reviews on both conceptual and detailed levels which may be required. Another observation that has been made is that none of the partner companies has a system in place that provides guidance and support on the consequences of decisions being made during product and manufacturing system design (*product and manufacturing knowledge simulation*). This is important considering that each decision, particularly if it is innovative, may largely impact the life of the factory e.g. the success of the products being developed or the changeability of the factory to accommodate new products and processes. The to-be simulation IDEF0 model is shown in Figure 7.





**Figure 7. To-be simulation IDEF0 model**

Since the scope of this study was to obtain qualitative results, surveys were carried out at five local manufacturing companies and thus their general validity remains to be tested. However, from the results, some trends have been observed that are independent from the company size and domain

- It is believed that innovation depends just on creative people and that substantial funds are required to employ new tools and solutions. However, in reality, with the right tools (e.g. thinking tools) and environment (e.g. trust, acceptance of other's points of view) everyone can contribute to innovation and with minimal costs.
- Stakeholder collaboration is considered an important means for enhancing innovation, mainly through the availability of more ideas. Artefact simulation is also considered important to analyse the feasibility of these ideas prior to implementing them in practice.
- The main inhibitors to using existing collaboration tools include lack of awareness and the perceived lack of necessity. In reality, by making use of the existing collaboration technologies, the need for face-to-face meetings can be largely reduced and the time gained can be invested on other activities for enhancing innovation.
- The main detriment to the take-up of simulation technologies is the perception of lack of return on investment of these tools. Many think that simulation tools are very costly to implement and their return is not enough to justify their expense. However, if used well, these tools can bring significant cost reductions which more than justify their investment.

In view of these observations, the next step of this research is to develop a framework by which product development stakeholders can be made aware of the available innovation, collaboration and simulation tools as well as their benefits so that they are more motivated to use them in practice with the ultimate aim of enhancing innovation in product development. The framework would thus serve as a portal to the available tools and techniques. Furthermore, it should also aim to provide a common representation for product and manufacturing system information so that the interfaces between the different tools in the portal can be facilitated.

## 7. Conclusions

From the literature review it was found that although research has been carried out on the topics of innovation, collaboration and simulation, these have not, to date, been considered collectively. This research thus aims to address this research gap by collectively considering innovation, collaboration and simulation support tools. From the results of the problem analysis carried out, it is concluded that product development stakeholders generally lack awareness of existing innovation, collaboration and simulation tools, or else are not motivated to use them due to perceived lack of necessity or perceived

lack of return on investment. Therefore, from the as-is and to-be models described in this paper, it is concluded that there is a need to amplify product development stakeholders' awareness and motivation to use these tools. It is after being aware of their benefits that they can be encouraged to use them in practice with the ultimate aim of enhancing innovation in product development. The next steps of the project thus involve coming up with a framework and eventually a support tool which help amplify the awareness of these tools as well as their benefits.

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