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A Research Capability on Management of Engineering and Technology

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RECAMM: A Research Capability Maturity Model for Managing Technological Innovations

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Abstract:

Companies, private and publicly funded research institutions have been engaged in research projects and research programs. This paper describes a research capability maturity model for managing technological innovations. The insights for this proposal were derived from studying a variety of research organizations for managing technological innovations in a publicly funded research institute in Singapore. The model was implemented over a period of time with different degrees of success in Kent Ridge Digital Labs, Singapore which has since been renamed Institute for Infocomm Research. The suggested maturity model has five layers – Ad-Hoc, Directed, Managed, Optimized, and Outsourced. Every research organization is likely to operate in any one of these five levels. The first fours levels can easily be managed entirely within an organization. The transition from the fourth to the fifth level is indeed very challenging and requires establishing the right set of frameworks for collaboration. The paper will describe the relationship between an organization's researchers and the research partners and the issues that become important at each of these levels. Some research organizations may have technology innovation directed research projects that operate across all the five levels. The paper will discuss the nature of technology innovation projects that lend themselves best to each of the five levels.

1. Background

Universities publicly funded national and state research laboratories and corporate research laboratories constantly wrestle with issues related to managing their research programs that produce technological innovations. We share some experiences gathered over a period of eighteen years while the author was at the Institute of Systems Science / Kent Ridge Digital Labs in Singapore. During this period the publicly funded IT software research lab was engaged in collaborative research with multinational corporations such as Ericsson, Siemens, Hewlett Packard, Apple, National Semiconductors, Fujitsu, IBM and several Singapore companies. It is the richness of observations derived from structuring these research collaborations combined with the experience of managing different types of internal research projects that provided the inspiration for developing the RECAMM research capability maturity model. The current morphing of this research lab is called Institute for Infocomm Research (www.i2r.a-star.edu.sg) [3, 4]. The reference section lists some related articles and websites [1, 2, 5].

2. The motivation for a research capability maturity model

Managing technology research projects leading to technological innovations are one of the most challenging management tasks anywhere in the world, simply because it is an exercise often aimed at inventing some shape or form of the future. The players involved in the process are highly qualified high achievers who often come bundled with high egos.

University based research where individual professors are largely free to pursue research of individual interest is at one end of the research management spectrum. At the other end of the spectrum lies targeted research carried out by businesses in response to a market need. Needless to say, management of research would be different for these two purposes.

Research and development are interpreted and managed differently by different organizations. They types of research departments of Physics and Biology would carry out in universities will be too early stage to worry about intellectual property protection. On the other hand any research carried out with a target product or service in mind will need to be managed with intellectual property protection in mind. The need to be concerned about intellectual property protection becomes more acute as a project migrates from the research to the development phase, especially into product development stage.

A research capability mature model will provide organizations with a framework that they could use for both benchmarking their current research management efforts and to decide on where they should position their research management efforts in the future.

3. The RECAMM

We recognize all technology innovations are the results of research projects. Hence in all the following discussions we treat management of research projects as equivalent to management of technological innovations.

RECAMM has five levels of research capability maturity as shown in Fig. 1. The first level is called Ad-Hoc given that there is no control of any kind. The second level is called Directed since the research projects managed at this level are typically in response to a need. The third level is called Managed given that the research projects have very clearly articulated accountability. The fourth level is called Optimized and generally reflects situations where a portfolio based approach is taken. The fifth level is called outsourced and this is when a third party is engaged to carry out research on behalf of an organization.

Level 1: Ad-hoc research

The lowest level of the RECAMM is ad-hoc research. An organization operating at this level of research management will allow research projects to be proposed based on the interests of individual researchers. Results from such projects are freely disseminated.

Individual researchers, Professors and students, belonging to the academic departments of most universities operate at this level. In fact, professors would often wince at the very thought of another entity controlling the nature and direction of research they pursue.

Many research organizations in publicly funded or corporate research labs are very likely to operate at this level in the early years of their existence. There are no direct Key Performance Indicators (KPIs) for the research outcomes since the research is ad-hoc.

The research outcomes from efforts positioned at this level are very unlikely to have any major commercial impact. As a result, any entity operating at this level generally has no major concerns about protecting any form intellectual property. University and other researchers freely explore and seek out research collaborations with similar minded organizations and individuals.

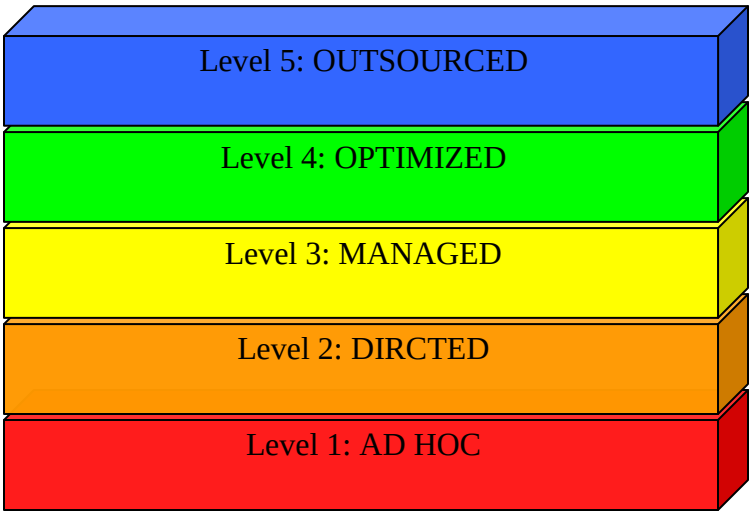

Fig. 1 Five Layers of the Research Capability Model RECAMM

Level 1 of research management works well for the management of exploratory and embryonic research. Such projects usually involve one or two researchers or a combination of senior and junior researchers. Junior researchers will include research

students in universities or research students on internships at corporate and other research labs.

The research results from such projects are often too early stage to have any significant market impact. Hence there is really no need to institute any IP management procedures for organizations, projects or entities operating at this level.

Level 2: Directed Research

The second level of RECAMM is Directed research. Organizations, projects or individuals operating at this level carry out research in accordance to the requirements specified by a sponsor in return for some funding arrangements. Such requirements specify broad areas of interest as opposed to specific deliverables. Examples of such broad areas are Nanotechnology, pervasive computing and grid computing. The deliverables from such research efforts are often proposed by those who apply for such directed research grants.

Some examples of directed research are the NIH and NSF funded research in the US and their counterparts in other parts of the world. Such projects may or may not have any restrictions on the freedom to disseminate the research results. Quite often the research outcomes are first submitted to the sponsors before being disseminated through other channels.

Directed research is carried out in universities through research programmes or research centers. Smaller scale directed research is generally structured as research programmes. Larger scale directed research efforts are structured as research centers. Examples of research centers are the Robotics Lab and CyLab in Carnegie Mellon University. There are several federally funded research centers of excellence set up in different universities across the United States using this model. These are typically funded for a limited period of time. Also, the researchers are almost all from the university, albeit from multiple departments and schools.

Directed research in publicly funded research labs are typically aimed at training manpower needed for a specific knowledge intensive industry. The Key Performance Indicators (KPI) for such research is the number of people trained from the program and the secondary performance indicator is the quality of publications.

Directed research in corporate research labs are often used for competency building. It may also be used for the purposes of positioning – i.e. sending a message to the world that the company has interest in the topic and is exploring product development opportunities.

The teams engaged in directed research are usually of significant size. Research programs can easily have a dozen or two researchers while research centers can have several dozens of researchers distributed across multiple research programs.

Directed research at universities and publicly funded research labs generally focus on post embryonic and emerging technology oriented research. Such research programmes and centers often offer freedom of collaboration and the license to freely disseminate the results. However, almost all of the members of the directed research teams often come from within a university or a research lab. At best, the team might consist of researchers from the university departments and publicly funded research labs. It is rare for such projects to involved researchers from outside given that university administrations are often reluctant to share the funds raised to third parties unless absolutely necessary. Even the directed research efforts within corporate research labs often enjoy quite a bit of freedom of collaboration and dissemination. They seek out academic partners in order to get to the cutting edge and do so through funding some research projects.

Directed research teams are generally made up of experienced and junior researchers from multiple disciplines. They are largely made up of researchers from the same organization with occasional consultants or short term visitors.

Given the considerable latitude for collaboration and freedom for dissemination of research results, there is really not much need for instituting intellectual property management processes. It might be useful for ask the researchers to articulate the likely impact of the research results on different industry verticals. Such exercises are often rare and the impact is almost always studied and listed against the applications specified by the sponsor.

Level 3: Managed Research

Managed research is very focused and is often disguised as advanced technology development in corporate research and development labs. Such research is generally product oriented and is pursued rather intensely with clear deliverables and time frames. The research is often a result of an early stage study that involved competitive intelligence and patent and other IP searches. Quite often companies study (potential competitors') positioning with respect to the topic of interest. Competitive intelligence reports from market news are used to determine (lack of) interest from potential competitors. Diligent analysis of the patents is carried out in order to identify white spaces that are ready for "capture and exploitation". Such analysis is often a prerequisitive before a proposal for managed research is crafted. Some times one finds that potential competitors have secured intellectual property rights of interest. A serious study is mounted in such cases to understand the possibility of creating surrounding intellectual property or replacement intellectual property. Surrounding intellectual property identifies new intellectual property that restricts the use of existing intellectual property by the competitors. This is achieved through some form of value addition(s) to the existing intellectual properties which will result in new products of greater value to the customers.

Universities and publicly funded research labs rarely engage in such managed research. Even when they do so, they carry out such research with a view towards licensing the

research outcomes. Therefore, all discussions in the rest of this section will be directed towards corporate research and development projects.

Corporate research and development groups, especially the development oriented research groups operate using the managed research model. Managed research teams are usually made up of researchers, engineers, product managers and marketing personnel. The teams are of considerable size and on occasions can be few hundred in strength. Consultants are brought in as needed and are given only the needed information. Consultants are rarely aware of the detailed or complete research project plans. They are given to understand that slice of the project that needs their inputs and the rest of the project is treated as a black box.

Given the serious market driven nature of managed research, such teams rarely engage in collaborations of any kind. When they collaborate with other companies, it would be on the basis of quid pro quo, i.e. joint development or exchange of intellectual property. Researchers from universities and publicly funded research labs are engaged as consultants with necessary non-disclosures and intellectual property assignment forms duly completed and signed.

Most of the results from managed research projects will not be freely disseminated until product plans are clear and products are announced. Most information is disseminated on a need to know basis and often under the cloak of a non-disclosure agreement.

Information flows freely upwards in an organization and very little information flows laterally or downwards.

Serious measures are required to be instituted for the capture, protection and management of intellectual property of all forms. Such intellectual property management measures might include filing a suite of patents as opposed to single patents. Such suite of patents might be to thwart the possibility of a competitor surrounding the current intellectual property with incremental intellectual property that is value adding. Several rounds of discussions might ensue to decide which of the surrounding incremental intellectual property needed to be protected and which of them could be let go. Significant resources and efforts would be expended on ensuring that each of the patents individually and all the patents in the suite collectively ensure a robust intellectual property positioning for the company.

Level 4: Optimized Research

Optimized research is often carried out at the corporate research and development organizations. Very rarely would there be an attempt at organizing optimized research strategies either in academic departments of universities or publicly funded research labs. The exception to this might be the case of some National labs that do not have an immediate interest in certain research areas.

Optimized research will take a portfolio based approach and will be a combination of the ad-hoc, directed and managed research strategies. In other words, organizations will decide on different amounts to be invested into each of the three types of researches. This will naturally follow their long term, medium term and near term interests.

For research of long term interest organizations will typically adopt the ad-hoc research strategy. They may even fund individual researchers to carry out research in a topic of interest to the company. For research of interest in the medium term they might partly or wholly fund research programs or centers of interest. National or regional efforts will invest in the setting up and total funding of research centers. Companies in most cases will fund complete research programmes of interest to them at third party sites or co-fund large programmes just to hedge. For research of immediate interest the companies will generally fund their internal research programmes.

In the case of large national funding agencies almost all of their funding will be directed at long and medium term efforts. Their interest will be to invest in multiple teams since it would be difficult to forecast which of the teams will produce the desired results. Whilst such organizations might use track records of research teams for funding purposes, they might be wary of excluding dark horses that might spring a surprise.

Optimized research strategy is a mixture of individual strategies at levels 1, 2 and 3. Hence the freedom to collaborate and the freedom to disseminate the research outcomes will be determined by the types of research funding. Similarly the treatment of

intellectual property will also be determined by the nature of research project – long term, medium term and near term.

Teams managing optimizes research are small and often operate on lines similar to the fund of funds in the venture capital industry. They fund the different types of research programs through respective funding centers. An example might be for a company to set up a university relations group to fund ad-hoc and directed research and the internal research management group to fund managed research projects.

Level 5: Outsourced Research

By outsourced research we refer to organizations that provide no support for any form of internal research. These are organizations that have decided to pursue an options model where in they retain the option of working with the best of breed in any area at the required moment. They are aware of the harsh reality that researchers often desire to remain in their area of interest even when the market opportunities have moved on. These organizations have realized that to change the interests of individual researchers working in their research labs is harder than to outsource the research to the best team out there in universities and publicly funded research labs. They also realize that the gap between research and commercialization is big enough that it is cheaper and less challenging to outsource all their research save the product development.

Outsourced research is also pursued as a strategy when an organization is very clear that it will focus on developing new products and services internally while outsourcing research efforts, especially the non-product development oriented research. One of the major proponents of outsourced research is Intel. Intel has been very clear that it will not set up a corporate R&D lab. It had significant investments into engineering related resources but shied away from setting up a research lab.

Clearly universities and publicly funded research institutes do not out source research. The will normally be the beneficiaries of outsourced research. Outsourced research as a strategy is practiced only by companies or large national organizations such as Department of Defense.

Organizations that outsource all their research would have understood the dynamics of the research world very well. They will have understood that any given topic is researched by armies of researchers across the globe and such research is rarely followed up by any serious attempt at productizing and that all such research is theirs for the picking at the right prize. They would rather wait and cherry pick the right results and perhaps the research team as consultants from among the different research teams that are in the rat race to find a solution for a given research problem. The second key understanding that they would have gained is that being ready to activate product design teams once promising research is identified is significantly more important than carrying out research in house.

Outsourced research is often managed by lean teams. These teams are often a bridge between the corporate product divisions and external research teams. Universities and publicly funded research institutions have been the recipients of outsourced research funds for long and medium term research. A somewhat simple example of outsourced research is the Original Design Makers / Manufacturers or also known as ODMs. Outsourced research is the model adopted when a company's strength lies elsewhere – product engineering, manufacturing, distribution, customer relations. Another example of outsourced research is industrial design. A third example of outsourced research is customer profiling / market research.

The intellectual property generated from such research almost always belongs to the company sponsoring the research. The entity undertaking such research certainly enriches its researchers in the know-how and competency but has no rights for dissemination of the results, collaboration freedom or the rights to the intellectual property generated from the research.

Above discussions are summarized in the table given below.

Research Capability Maturity Level	**Prevalence in Univer-sity based research labs**	**Prevalence in corporate research and development labs**	**Time sensitivity**	**Degree of freedom for external collaborations**	**Degree of freedom for Dissemination of research outcomes**	**Control of intellectual property issues**
Ad-hoc	High	Low	Long term	High	High	Poor
Directed	Sparse	Medium	Medium term	Medium	High	Weak

Managed	Rare	High	Near term	Low / Limited	Low / Zero	Strong
Optimized	None	High	Mix	Mixed	Mixed	Mix
Outsourced	None	High	Near term	High	Zero	Strong

4. RECAMM in action at Institute of Systems Science / Kent aRidge Digital Labs

Institute of Systems Science started off in Level 1 in the year 1985. It had an early taste of directed research in 1987 when Singapore Telecoms commissioned a directed project on Teleview. Teleview was a project to build Internet based applications on existing Plain Old Telephone Lines (POTS). In mid 1990s Institute of Systems Science and Apple entered directed joint research collaboration aimed at developing solutions for handling Chinese on computers. Between 1995 and 1998 Institute of Systems Science carried out outsourced research with Hewlett Packard on information security related solutions, with Siemens on Dynamic Policy based Mobile IP solutions and with Fujitsu on the development of a SGML database management system as a component of their Active Information Sharing System initiative. All these are examples of outsourced research. Since 1998 Institute of Systems Science was merged with Information Technology Institute to set up a market focused entity that was named Kent Ridge Digital Labs (KRDL). KRDL adopted both Level 3 and Level 4 approaches. It had joint research projects with other research entities such as TNO of Holland and CNRS of France. At the same time it defined managed research projects that were market oriented resulting in the creation of twenty technology based start ups. These start ups went on to raise a total of S$ 120 million from venture capitalists and corporate investors. Twelve of

these companies are still in existence despite the tough market conditions following the Dot Com debacle starting 1999 and the tough economic situation and apathy to technology based companies and emerging IT solutions that followed. As observed, KRDL itself did not outsource any R&D to third parties.

5. Making the transition from one to the next level

As mentioned in the beginning of the paper most organizations start with ad-hoc research in their early stage of existence.

Academic departments in universities will remain by and large in level 1. Publicly funded research labs and corporate research labs will make an effort to transition into higher levels.

The following table suggests steps for transitioning to higher levels.

Transition	**Definition of Research areas / Topics**	**Policy on Collaboration**	**Policy on Intellectual property**	**Policy on dissemination**
Ad-Hoc to Directed	Announce general areas of interest and invite proposals against such areas only	Identify selected partners for collaboration	Establish a lightweight intellectual property watch to capture the occasional and rare opportunity.	Sensitize researchers on voluntary disclosures of results that they consider might be worth protecting.
Directed to Managed	Identify the specific product or solution	Seek collaboration in exceptional	Require that all research teams submit	Approval for external publication is to

	opportunity. Assemble a team to create the desired outcomes. Require competitive intelligence and patent analysis to be carried out as part of the project proposal.	cases when absolutely needed. Use consultants otherwise.	invention disclosures. Institute close scrutiny of all aspects of IP for every research project. Institute processes for IP protection.	be obtained explicitly.
Managed to Optimized	Establish a portfolio management decision framework. Set aside contingencies for unexpected new research opportunities.	Establish relevant collaboration policies for each of the types of research projects – Ad Hoc, Directed, Managed and Outsourced.	Establish multi-tiered IP management policies and processes to address all types of research projects.	Establish multi-tiered publication policies and processes to address all types of projects.
Optimized to Outsourced	Establish clear monitoring policy and processes for tracking all research topics and teams of interests.	All business partnerships are on outsourcing based. Collaborations to be pursued only as an exception.	All IP arising out of outsourced research to be owned by the sponsoring company.	All publications relating to research to be vetted by the sponsoring company before dissemination decision is made.

6. Summary

The paper presents a framework for managing research projects resulting in technological innovations. The paper defines each of the five levels of the framework. It also outlines recommended policy and management issues for transitioning from one level to the next. We hope that this framework would inspire organizations to examine their current practices and make necessary changes. We also hope that practitioners and researchers of

research and technology management will come forward to continuously refine this framework towards a sophisticated standard model that could be adopted across multiple industry verticals.

7. References

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