Architectural and Modular Innovation: An Extended Research Framework

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Abstract

Innovation is very important in current times. It is a major weapon that enhances competitive advantages. Four types of innovations are reported in literature: continuous improvement, modular innovation, architectural innovation and radical innovation. In this paper we give theoretical framework that relates modular (MI) and architectural innovations (AI) to different organizational variables. Contribution of authors on modular and architectural innovation is scattered. Here we put all these in one place. In this paper we present eighty nine theoretical propositions.

Key Words:
Architectural Innovation, Modular Innovation and Organizational Variables)

1. Introduction

In this paper we relate AI/MI to different organizational variables, these are strategy, personality, culture and structure of the organizations. We start with strategy. Different strategy types are given in Miles and Snow et al (1978). It is reproduced below for ready reference.

Strategy-

Strategy is derived from the Greek word which means the art of leaders of troop wherein it was defined as "general plan for the achievement of long term or overall goal under uncertain conditions". (Michael porter, 1980) defined strategy as "formula of a business to compete, defining business goals and framing different policies to achieve those goals". He provided different type of strategies named Cost leadership, Differentiation and focus to cope up with 5 competitive forces (i.e. Suppliers, buyers, new entrants, Competitive rival and Substitutes)

1) **Cost leader**- Firm by adopting this strategy try to gain market share by providing lower cost value and by doing so it gains competitive advantage over other rival firms. To provide low cost generally firm produces large volume of products to have benefits of economies of scale (CL).
2) **Differentiator**- Firm adopting this strategy tends to differentiate its products on some or other basis like offering innovative products or some other certain differentiating criteria like building its product brand image, and try to charge higher price. (Porter 1980 and 1985) (DIFF).
3) **Focus**-By this firm tries to focus on the particular buyer or on producing particular segment of product. By having the focus strategy firm can focus on differentiating its products or providing low cost.

Miles and snow (1978) gave strategies to solve engineering, administrative and entrepreneurial problem and named those strategies as defender, prospector, analyser and reactor. Wherein he defined-

Analyser - as Organizations that operates in turbulent as well as also in stable arenas. Depending on different situations analyzer adopt different strategies i.e. Follow formal process and structure in stable and routine environment whereas during turbulent times they observe their competitor closely and if find it to be promising then follow them.

Millers and Roth (1994) identified 3 manufacturing strategies wherein one was named innovator. He defined it as-

Innovators basically focus on Changing in designs, Technological wise doing certain innovations, designing new product and introduce the same to the market (INNO).

Rebecca Henderson and Kim Clark (1990) and Burgelman et al (2004) in their paper/book have talked about 4 kinds of product innovation named Incremental, Radical, Architectural and Modular innovation. These are defined below-

1) **Continuous /Incremental innovation**- this type of innovation is done by improving, refining and exploiting the existing innovations thus is predictable, reliable and have low risk. Components existing concept gets strengthened without affecting its traditional linkage (CI).
2) **Radical Innovation**- Radical innovation involves discontinuation of status quo and focuses on development of new competencies and thus includes innovations that improve the performance. Hence different aspects i.e. technology, market, organization gets affected very frequently (RI).
3) **Architectural Innovation**- It links the existing components altogether in a new manner. It changes the components in such a manner such that the new linkage or new interactions gets created with other components. It generally relies on already proven technology and take lessons from them and apply the same in new market (AI).
4) **Modular innovation**- It changes only core design concept without changing the products whole architecture (MI).

Personality types details are given in Wiki (see the link below).

MBTI- Myers-Brigs type indicator is used to assess the personality. It was developed by mother- daughter Katharine Cook Briggs and Isabel Brigg Myers. It's a test using 100 question that tests the personality by asking questions that how and why people feel and behave in a certain way in any particular situation. Based on the responses the respondents are classified in 4 pairs of 16 personality types-

1) **Extrovert and Introvert**- Extrovert are the people who are social in nature having outgoing personality whereas introverts are shy, timid and quiet
2) **Sensing and Intuitive**- People who prefer practicality as well as routine and order are sensing types whereas Intuitive are those who rely on big pictures and are not so practical.
3) **Thinking and feeling**- People using logic and reasoning for solving any problems are thinking types whereas people relying on their values and emotions are of feeling types.
4) **Judging and perceiving**- people who prefer order and structure are of judging type whereas people who are flexible and spontaneous are perceiving types.

Big 5 theory of personality- Big 5 model is also known as OCEAN model. This theory says that there are 5 dimensions that cover all the major variation of personality of humans. They categorised those dimensions as-

1) **Extraversion**- People having qualities to assertiveness, social and gregarious are said to be extravert whereas people who are quiet and reserved in nature are said to be Introvert.
2) **Agreeableness**-The people who are having cooperative and good nature are high on agreeableness whereas people who are uncooperative, antagonistic are low at agreeableness.
3) **Conscientiousness**- People who are responsible, organised and persistent in nature and are reliable are high in conscientiousness whereas people with low score are not reliable and are highly irresponsible and disorganised.
4) **Emotional stability**- Its ability of the people to handle stress hence if person is self-confident and remain in calm and cool manner in any turbulent situations are said to be emotionally stable whereas people who don't have such qualities are emotionally unstable.
5) **Openness to experience**- People with qualities like creative, artistic and curious in nature are open towards anything and any new situation. They try to do something unique and novel.

We relate the AI/MI to organizational variables such as culture and structure also. We give a brief on these below. Cultural dimensions such as power distance, uncertainty avoidance, individuality/collectiveness, short/long term, masculine/feminine, indulgence (Hofstede, see Google pages); and also others such as bureaucratic, professional, person support, market and adhocracy. These are self-explanatory.

Now we refer to structure. Organizational structure dimensions are given in Wiki pages and these are: standardization, specialization, centralization, formalization and complexity of work flow. These are also self-explanatory.

2. Research Framework

Below we present arguments for the following. In AI (Architectural Innovation) knowledge workers will be empowered; and there will be higher need for horizontal integration and higher accountability at the level knowledge workers. In Modular Innovation, strategy will be at the top level; and operations will be decentralized.

In Modular Innovation (MI), various modules are tied in a same structure (that is known in technical terms as Product Architecture. System performance goes up as these modules' performance increases. It has been noted by authorities that here first mover has no first mover advantage.

In Architectural Innovation (AI), the modules/components are arranged in different order, and then whosoever does it first, puts in more engineering effort to go up the Technology S curve. And it has first mover advantage.

For more details about AI and MI, look up the references given below.

Below, we give interesting hypotheses/propositions that industry professionals and academicians will find useful.

As per above, in MI, many modules, components are outsourced that are NOT critical. As it is said supply chain is as efficient as its weakest link, these 'critical' modules are developed in house; and all other are delegated to many suppliers (with many suppliers for a component/module). And therefore there is very little interaction between suppliers and core company, that is to say it is low on network based interactions. In modular innovation, input and outputs are defined; and the whole module is treated as a black box. Hence we have the following.

(H1): In Modular Innovation, the core company will have higher score on 'centralization'; and will be not interested in 'networking' with the suppliers in general.

Architectural Innovation has to be made successful by knowledge workers, as they have the knowledge to put different components in a new sequence. Generally (high) bureaucratic controls are put on for the ease of KM (the Knowledge Management). These need to be relaxed for a while for encouraging creativity. Hence we have the following. It is well known that in AI we have to breed millionaire entrepreneurs (see INTEL case, WIKI). Hence we have the following.

(H2): In Architectural Innovation knowledge workers are empowered; and controls are relaxed.

In Architectural Innovation (AI) product architecture is frozen (centralized strategy) and various module developers are given free hand as far as they follow the input to module and output from the module (operations are decentralized). Hence we have the following.

(H3): In Modular Innovation, we have centralized strategy; and have decentralized operations;

In light of discussions for H2, we also have the following.

(H4): In Architectural Innovation there is greater need for horizontal integration; and there is greater accountability at the lower levels where the knowledge workers are operating.

Here we gave some interesting propositions on AI and MI. In nest paragraph we come up with few more propositions.

Several studies in technology strategy indicate that one must not have too broad patent portfolio strategy (as it leads to decrease in profitability. And some have argued that retain only those patents that are useful in some sector business that one is already in. We argue in this paper that patent portfolio strategy is different for type of innovations, that is, Architectural and Modular innovation. We argue again that a firm with Architectural technology has to be aggressive, and a firm focused on Modular innovation need not be aggressive (as there is no first mover advantage in Modular technologies). Several interesting propositions are given.

A good review on architectural and modular technologies is available in Wiki. In innovation literature it is common to talk about total knowledge in a sector OR industry. And if one is pioneer or leader, then it is natural that they posses most of the knowledge in the sector/industry. These have implications for the patent portfolio strategy (PPS) of the firm/company in question. We also evaluate the need for aggressive PPS for a given firm. Here we argue that PPS is influenced by its competitors (external factors) and the extent of diversification a firm does (internal factors).

For a good review of various issue of technology management is available in literature.

(H5): In Architectural technologies the firm must possess as much Knowledge as possible from the Knowledge available in the industry where it is operating (this is because there is first mover advantage and gains are enormous because of advantages of getting up the technology S curve). Hence here there would be much higher level of ‘networking’ with its environment.

Authorities have said that one must keep all related patents that are needed (for use in different businesses) to be kept with you (taking an internal view of PPS); and all other patents be divested. Now it is modified as follows. It now means is that the one’s PPS (patent portfolio strategy) is also driven by what one’s competitors’ are doing.

Since organizations pursuing Architectural Technologies already have most of the Knowledge they need, then they can easily afford to be aggressive in acquiring all remaining Knowledge/Patents which are anyway less in numbers.

(H6): In modular technologies, identify those modules that limit the performance of the product; and these are labelled as critical; and these must be cultivated in house and must have all the Knowledge (OR as much Knowledge as possible) in organization; and other modules are outsourced.

(H7): Since in component(s)/modular innovation first mover advantage is not there, they need not be aggressive in terms of investment behavior, patent protection and acquisitions etc. (in relation to AIs). In AIs, greater the velocity of technology change, higher will be the aggressiveness.

(H8): If the firm also has some architectural technologies and some modular technologies, in critical modules (in architectural phase) firm has to be aggressive. Then it will lead to non-uniformity of culture.

For Radical innovation, the organization must have all the Knowledge in the world.

(H9): In firms engaged in architectural innovation, the degree of overlap in knowledge of all firms of the entire sector (compared to the knowledge available in a given company) will be much lower than the degree of overlap in knowledge of all firms (compared to the knowledge the available in a given company) all the firms in the entire sector pursuing modular technologies.

Here we give an approach to frame the PPS of a firm. Several interesting propositions are given, and we hope that these will be useful to academicians and practicing managers alike. An empirical investigation is underway to verify framework given here.

Here we argue that Modular Innovation has less risk and is suitable for risk averse entrepreneurs; while Architectural Innovation has high risk and it should be followed by risk prone entrepreneurs. And we also argue, by extending Management Control Systems, that modular innovation is 'supplier centric'; while architectural innovation is to be treated as 'investment center'. We give interesting hypotheses below.

It is quoted in literature that in AI (Architectural Innovation) companies often face the dilemma of drawing surplus from current technology (that is the bread butter today); and putting it in new technology. It is also true that top management is not responsible for success and failure of AI; and at the same time they (top management) have to put as much money as demanded by technology workers. AI is backed up by having large number of in house patents. Architecture I: 'resources and strategy centric' (investment center) as lot of resources will be put in; so that we go down the technological S curve much earlier, and gain a huge advantage later on. Hence we have the following:

In modular innovation (MI) the core company only needs to keep those technologies in house that are critical to system performance; and rest are generally outsourced. Here the core company has to ensure that there is enough redundancies in the system, so that a module can be supplied by many even if anyone supplier exhibits opportunistic behavior. MI is has much less number of in house patents (compared to AI). Hence we have the following:

(H10): Modular Innovation will be SUPPLIER CENTRIC' (supplier center).

(H11): Architectural Innovation can facilitated (with very high chances of success) by combining researchers drawn from diverse backgrounds as it requires high diversity;

(H12): In Modular Innovation not much diversity is required (in terms of technology diversity at the core company level).

In earlier works, executive compensation has be related to national culture and personality of the employee and strategy of the firm. Almost nothing is available in literature that relates executive compensation to type of innovation i.e., Architectural Innovation and Modular Innovation. An effort is made to bridge this gap. The framework is given below.

(H13): In AI (Architectural innovation), top management is NOT responsible for success/failure of the project. Hence he would not be paid higher. If he can contribute to technical problem solving and he can command respect of AI knowledge workers, then he could be paid higher as per the group incentive scheme.

(H14): In MI main job of top management is to develop the supply chain of many vendors, and see that their bargaining power of suppliers is not too high; and ensure that the knowledge is maintained in core organization of nearly all modules (to deal with the contingency. Also they contribute by managing modules in house that are the bottleneck. Thus they would NOT be paid much higher for their contributions.

In innovators, K worker is the most important entity & he would be paid much higher (see Google Page: Creating Millionaire Entrepreneurs at Intel).

The framework above beats the conventional understanding that higher the uncertainty needs to be compensated by higher pay.

Purchasing patents/licensing is no substitute for transfer of Tacit knowledge acquired/transfer. And it takes very large time of association (between company that has generated the patent and the company that has purchased it) before we can fully assimilate the Tacit Knowledge.

(H15): Architectural innovation involves much higher content of Tacit knowledge; and hence in Architectural Innovation (AI) large number of patents have to be generated in house. In the context of Modular Innovation, in critical module large number of patents have to be generated in house. (in the same vein as H1).

(H16): In the context of Modular Innovation, in non-critical modules, we can purchase patents or get a license and try to figure out the tacit K at a little leisurely pace by starting the exploitation process (so that the scarce resources of Explorative scientists be deployed elsewhere).

(H17): In Modular innovation, in bottleneck modules, there is substantial time pressure, and then it is necessary to keep exploratory and exploitative USR (under the same roof).

(H18): In Architectural innovation there is high degree of time pressure (one has to go up the technological 'S' curve so that one has advantages of first mover). Hence we have to keep Exploratory scientist and Exploitative people USR (Under same roof).

Here we relate AI and MI to open innovation (refer to wiki page).

(H19): When there is first mover advantage: Architectural Innovation: then do not go for open innovation; where there is no first mover advantage: as happens in Modular Technologies: go for open innovation;

(H20): Probably, in modular innovation, one may go for 'open innovation'. So seek external innovations (by taking licenses from others: also patents can be acquired at low cost) and as a barter deal license your technology. This would be valid in low/medium velocity technologies.

In high velocity environments (patents will be very costly): 'open innovation' will not work, as it (open innovation) takes more time to happen; and Tacit knowledge cannot be acquired in a short time. Hence we have the following.

(H21): In high velocity environments, almost all the patents will have to be generated in house.

(H22): In low velocity environments, 'open innovation' will give best results.

Now we relate AI / MI to strategy of organization (at conglomerate level: see wiki pages), culture and personality types.

(H23): Conglomerates where Horizontal Strategy is implemented should go for ARCHITECTRAL innovation (for competitive advantage).

(H24): Conglomerates, where Horizontal Strategy is not implemented, should go for modular technologies/innovation.

(H25): Diversified Majors it is recommended that they use ARCHITECTURAL innovation

(H26): In EXPLORATION right balance of deviant behavior and cohesion is required; and in EXPLOITATION Cohesion is required.

(H27): In architectural innovation the required cultural dimensions are as follows: low power distance; low uncertainty avoidance; high collectivism; high masculinity; low bureaucracy; high professional and high on adhocracy.

(H28): In modular innovation the required cultural dimensions are as follows: high power distance; low uncertainty avoidance; high masculinity; low bureaucracy and high professional.

(H29): In architectural innovation the required personality dimensions are as follows: high on extroversion; intuitive-thinking, intuitive-feeling, high on openness to experience and high on systematic.

(H30): In modular innovation the required personality dimensions are as follows: high on extroversion; Sensing-Thinking at core company level as it interacts with suppliers; and at critical module level in the core company level it will be same as in architectural innovation as in (H29) .

Here we give few propositions on architectural/modular innovation. We argue that variance of return on AI is high; but previous success in AI leads to high degree of success in following architectural products. And that variance of

return on MI is not too high; but previous success in MI does not lead to degree of success in following architectural products. This has implications for investor community. We give interesting propositions here.

(H31): The more the risk the management will take, the more the money will be allocated to Architectural Innovation (AI).

(H32): Also wherever (in AI) there is advantage of first mover, those innovation projects will get max priority (in terms of funds allocation).

If the modular innovation (MI) is lagging behind, then with little effort it can be made up by putting little/moderate effort in the 'critical' module; hence MI (modular innovation) has less variance on rate of return; and in AI (architectural innovation) variance on rate of return would be high. This is true as uncertainty is H in AI and low in MI.

(H33): In architectural innovation (AI), variance of rate of return is very high.

(H34): In modular innovation (MI), variance of rate of return is low.

S1: It is suggested that as patent portfolio gets too broad, then profitability declines.

(H35): S1 is valid for 'technology' conglomerate level; where one is supposed to divest a patent if it is not useful to more than one business unit (BU) or strategic business unit (SBU).

(H36): But S1 is NOT applicable to architectural innovation; as here the base of patents is very high and they (AI) force the patents aggressively by the legal route.

(H37): S1 is NOT true in MI (modular innovation) as the firm has patents in multiple technologies (especially in a collection of modules that tend to be critical). In MI the firm does not enforce the patents aggressively; and generally gives it to suppliers on a licensing basis. So whenever the patent portfolio is broad, license it to suppliers.

Now we relate innovation to Taguchi Methods. In continuous improvement Taguchi (T) methods are already in use. It is proposed that machine learning can be fruitfully used here. Output of T methods can be fed to machine learning software; so that it can be trained quickly. After successes each time, this information can be loaded in machine T Methods and cognitive maps) for a faster response.

(H38): This approach can be useful in both architectural innovations. Here T methods are useful (for architectural/modular innovation); and so is machine learning. And we feed the output of T methods to machine learning for a very rewarding experience as machine learning will be quickened.

Now we relate innovation to uncertainty.

(H39): In modular innovation high velocity domain, go for licensing (to recover as much money as possible) and litigation (cost of litigation is low) is avoided.

Some studies have recommended that patent portfolio should not be too broad; and larger the patents leads to less profitability. We argue that this depends on level of uncertainty. If uncertainty levels are higher, then larger will be patent portfolio to offset higher risk. So now we are in a position to state the following.

(H40): For architectural innovation, if you have much higher uncertainty, then we need to have patent portfolio that is much broader.

It has been stated in literature that in modular innovation we need to outsource many modules to suppliers that are not bottleneck; and in MI only the critical modules are kept in house.

(H41): Royalty income (obtained by licensing of patents to suppliers) will be higher in Modular Innovation in low velocity domain; and will be low in high velocity domain; and in architectural innovation profitability will be higher

in relatively low uncertain environment architectural innovation will clock higher profits than in relatively high uncertain environments.

In AI (architectural innovation) a firm has to acquire large number of patents; and enforce it legally. In high velocity environments AI will be required to possess a very large number of patents, and face the risk of it getting outdated. Where as in modular innovation (MI) that follows the approach of licensing the technology (of non-critical modules) is not affected too adversely. Hence we propose the following:

(H42): In high velocity environments, Modular innovation has much less risk (as seen from the angle of keeping large number of patents that perish early) than the firms following Architectural Innovation.

In low velocity environments it is just the other way around. In this case fortunes of MI do not change drastically; but for AI it becomes much easier; as it can acquire large number of patents with very little risk. Hence we propose the following.

(H43): In low velocity environments, fortunes of Modular innovation do not change that much; but AI (who is a first mover) will be more profitable.

To keep smooth progress of work (as employees leave etc.) we need to keep redundancy (keep more employees than that are normally required). Organizations are now-a-days keeping ESM (Enterprise Social Media) to assist in K management. Now we can state the following and it is easy to see.

(H44): In high velocity environments AI (without the use of Enterprise Social Media) has to keep much higher level of redundancy; and not so in MI.

(H45): In high velocity environments AI has much more risk when viewed from the angle of maintaining a large base of technology workers (called as redundancy) to manage the tacit knowledge. And unless organization has very large resource base, AI strategy is best to be avoided.

Now we relate personality of CTO (Chief Technology Officer) to innovation types.

(H46): It is proposed that, when low velocity environments, exploratory/ exploitative work will be done under the different roof; and in high velocity environments, exploratory/exploitative work will be done under the same roof.

(H47): Personality of CTO in a firm with modular innovation will be nearly same as personality of CTO architectural innovation, in low velocity environments. And it will be Sensing-Thinking, Judgmental and systematic.

(H48): In high velocity environments personality of CTO in MI will be Intuitive-Thinking, Intuitive-Feeling, open to experience; and will be ambidextrous in relation to Judgmental/Perceptive dimension of personality. CTO in AI has to acquire expert based power.

(H49): CTO in AI need to have ambidextrous personality in high velocity environments; and it will add very high degree of stress (on CTO). And it will make the CTO a neurotic person.

Now we relate knowledge management to types of innovation.

(H50): In modular innovation (MI) tacit knowledge is managed as follows. (i) Maintain Hub and Spoke type of communications; and encourage suppliers to share knowledge among suppliers through the Hub and spoke model of communication with core company at the hub. In the process supplier gets another technology (for a different module) from their fellow suppliers. Give more incentives to supplier to gain competence in more than one module. After technology licensing is done, more innovations are done at supplier end. This is to learn (at the core company) by maintaining ESM at the hub (the core company). Thus the core company can keep knowhow at their place.

(H51): In architectural innovation we need to organize ESM among the modules that are to be arranged in different order (as it is finally arranged in different order). Therefore, the number of ESMs in AI are much higher. than a comparable company doing modular innovation. Due to redundant work force in AI, it will generate much larger data

than in MI. Also bureaucratic controls for converting tacit to explicit will be prevalent in AI (as it has very large number of patents and large number of knowledge workers) than in MI. This is so because if number of transactions is much larger, then one need to document them to ensure that irrational actions/ decisions are not taken.

(H52): Adhocracy is practiced only in AI, RI and MI (in MI it is only required in critical modules) & NOT in continuous improvement. One gives stock options in AI and in MI (in MI it is only for critical modules are on the floor).

Now we relate culture and personality to type of innovation.

(H53): Power Distance in MI to be moderate, and low in AI, Uncertainty avoidance to be moderately high in MI and very low in AI, collectivism to be high in AI and moderately high in MI; bureaucracy to be significant in AI and not in MI; adhocracy to be high only in AI (in low velocity environments only & not in high velocity environments).

(H54): Also in AI in high velocity environments people should be low on Neurotic (should not lose his calmness in stressful conditions) as on all other dimensions it is required to be ambidextrous (like good extrovert and a good listener; agreeable (not doing altercations) but to put in objections. To avoid GROUP THINK; to be perceptive and not spend too much time in analysis; systematic for good planning but allow space so that creativity is not stifled etc); then it puts the persons under tremendous stress. (Ambidextrous personality is under tremendous stress; as person gets down to his natural style most of the times; and feels the stress as he puts in other kind of behavior).

(H55): In low velocity environments, persons in AI to be Intuitive-Thinking, Perceptive; open to experience and systematic. Similar profiles will be required in MI.

(H56): In innovative organizations we need ambidextrous personalities that can integrate diverse viewpoints. These persons are typically agreeable, systematic, perceptive and have strong sense of intuition. They do not have value rigidity; which means they do not have strong parent; but have good child and adult.

Now we relate concurrent engineering to types of innovation (refer to relevant wiki pages).

3D concurrent engineering (3D CE) is about designing product by taking feedback simultaneously from different sections of organization and also supply chain members.

(H57): In MI, in noncritical modules, 3D CE will easy (compared to AI) but in MI, for critical modules 3D CE will be difficult (than in non-critical modules).

In modular innovation we can offer variety of products with no increase costs.

(H58): In Modular Innovation (under low certainty environments) product development is done mostly in house; PPC would be easier and SC design also not a problem (as production is outsourced) and 3D CE would be easier. Here risk will be not high.

(H59): In Modular Innovation (under high certainty environments) product development is done mostly in house; and SC design is a problem (as production is outsourced as earlier to avoid risk of investment & the attendant problems of Alignment & Adaptability will be serious as triple A is one of the bases of differentiation) and 3D CE would be difficult. These products are expensive & target customer is affluent.

Tech licensing will be very high in Modular Innovation (MI); and very less in architectural innovation (AI). Compatibility issues will be lower in Modular Innovation than in Architectural Innovation.

(H60): Technology development cost will be higher in architectural innovation; as the over head cost of maintaining huge no of patents is high compared to the same in modular innovation. There is more pressure on AI to reconfigure its technology and spawn many business that are MI/ Differentiators. In general this is true for technological beachhead (as ME Porter) argued. Examples are P&G in paper products; and Toyota in Engines technology.

(H62): Modular innovators idea generation to market is faster than AI (in high velocity environments).

Now we relate outsourcing to innovation type.

(H63): Modular innovators (MI) tend to keep bottleneck technology in house; and outsource the rest to suppliers. They do innovation, take patent and license it to suppliers. The supplier tends to overcharge to you, but that is fine. However if they constantly do machine capability analysis; and do process optimization (such as Taguchi Methods) and manufacture the product in house, then they can make it in much less cost. Similar approach can be followed by firms with differentiation strategy at least for very costly components.

(H64): Machine capability analysis will be done at a high level in cost leaders; it will be done at a very high rate in differentiators and it will be highest in innovators (as word of mouth spread by early adopters is very crucial) in general.

(H65): In innovators, machine capability analysis is high in modular innovators and radical innovators and continuous innovations; and highest in architectural innovators where there is first mover advantage (and this advantage should not be squandered).

Following is given in the context of high velocity technology.

(H66): Architectural Innovation: Idea generation can be done on VTs (Virtual Teams). And since the knowledge involved is TACIT, for Architectural Innovation Implementation, physical proximity is must.

(H67): For Architectural Innovation, SBU (strategic business unit) structure is recommended (with physical proximity (as Tacit Knowledge is to be shared)).

Conjecture 4: In modular innovation, engineering effort required is less. Refer to wiki pages on virtual teams (VT) and enterprise social media ESM).

(H68): In architectural innovation significant engineering effort is used in systemic integration.

A1: It is reported in literature that for Architectural Innovation management is not responsible for success or failure (of AI). In this context we give the following.

(H69): In AI organizations organization coupling is very loose, and hence there is a danger of organization getting split along the informal lines; and in AI management has to protect its IPR by the use of law.

(H70): In general in innovators one must encourage internal competition to address the concerns in (a1). For this, one may use flexible structures that can be dismantled after its purpose is over; and create fresh flexible structures as needed. We argue that innovators need to manage processes of collectiveness and competition. This issue (balance the collectiveness and competition) is of moderate difficulty in differentiation; high difficulty in modular innovation; and of very highly difficulty in architectural innovation.

(H71): In modular innovation organizational coupling is tight; and in incremental innovation (as in JIT), organizational coupling is highly tight; and in radical innovations organizational coupling is highly loose. Hence we can say the following.

(H72): Looser the organizational coupling, higher should be the legal protection of IPR.

(H73): Design rules are required in Incremental Innovation; and one must have flexible or dynamic design rules are recommended in Modular Innovation, Architectural and Radical Innovations (with dynamism in increasing order: low dynamism in MI, and highest in RI).

(H74): In exploitation: one needs tight coupling and in explorations one needs loose coupling; and hence when these (exploration and exploitation) are done under one roof (USR) one needs AMBIDEXTROUS personality; and here participants will be under significantly more stress. This will happen in smaller innovative organizations who cannot afford UDR (exploration and exploitation under same roof.

It has been reported in literature that Technology Transfer is similar to Architectural Innovation. Using this we give following conjectures (and not hypotheses because in this field no work is reported).

Conjecture 5: Technology Transfer in modular products is easy. This is true because at most we have to change the input-output specifications of different modules. The product architecture is not disturbed.

Conjecture 6: Technology Transfer in products that come out as an output of architectural innovation is difficult. This is true because we have to do much more than change the input-output specifications of different modules. The product architecture may also have to be disturbed.

Here we consider small firms engaged inAI/MI.

(H75): Small firms are likely to succeed in low velocity architectural and/or in modular innovation.

(H76): Small firms are NOT likely to succeed in high velocity architectural innovation. Here the concerned organization is big with huge resources; and have the ability to legally force patent violations.

(H77): In high velocity technology small firms are likely to succeed in modular innovation.

This comparison of organizational structure is between modular and architectural innovation; and these are not to be compared with traditional cost leaders and differentiators.

(H78): Centralization (will be higher in terms of relations with suppliers), formalization, specialization and standardization will be higher in organizations pursuing modular innovations (MI). Here interactions between professionals will be streamlined.

(H79): Centralization, formalization, specialization and standardization will be lower in organizations pursuing architectural innovations (AI). Here interactions between professionals will be complex.

Conjecture 7: When AI takes over a MI firm, it can easily do the knowledge management required (that is with suppliers and modules that are on floor). And when that is done, there is lot of synergy between MI and AI. Thus we argue AI acquiring MI would be easier; and MI going the AI will be difficult.

Here we discuss implementation style for AI/MI.

(H80): In high velocity technology area, architectural innovation has to be implemented in big bang manner (as we have first mover advantage).

(H81): In high velocity technology area, modular innovation need not be implemented in big bang manner. Rather we can go in incremental manner.

There is no first mover advantage. Fall out of above: young entrepreneurs (with thin resource base) should get into modular innovation (despite competition being high).

Here we discuss organization forms suitable for AI / MI.

(H82): Architectural innovation (AI) needs aggregate forms of organization.

(H83): Modular innovation needs modular forms of organization.

(H84): Within a module if there is AI, then it needs aggregate form of organization.

Here we discuss market orientation, and use of contingency theory in AI / MI.

MI/AI are highly oriented towards early adopters.

(H85): MI: competitive relationship with suppliers (as they have more bargaining power).

(H86): AI: will tie down its suppliers (as it forces its patents in court of law: in a coercive manner) and bargaining power is with AI.

(H187): In AI use of contingency theory (of decision making) will be used more frequently than in MI.

Here we throw some light on management of analysis / paralysis syndrome in AI / MI.

(H88): Concept of managing nervous energy (Selznick) is very crucial in architectural innovation; and not so much (in relative terms) in modular innovation. If competitive forces are too much (and unhealthy), organization may split along informal lines. And if there is high cohesion then innovation suffers.

(H89): In AI personality types such as NT/NF/Open To Experience will generate large number of alternatives; and we need personality types such as systematic/Stand SF to apply rules (as has been expressed in literature) to cut down the alternative phase and control costs. In MI this phenomenon is NOT that severe; as it is in AI.

In keeping with the spirit of adhocracy: in AI the knowledge workers in collaborating product to be in the small teams of AI: as per their choice; and this can be changed if the person feels so.

Table 1: Relating AI/MI to Organization Culture

	Architectural Innovation	Modular
Power Distance	H in enforcing patent and in knowledge leakage to its competitors; and L elsewhere	H due to explicit K in may modular products; and L otherwise
Uncertainty	Very high	High
Individuality / collectiveness	Collectivism: H	Collectivism: L
Short Term / Long Term	More LT	LT
Masculine / Feminism	Masculine: H	Masculine:H
Bureaucracy	Masculine: H	Masculine: H
Professional	H	H
Person Support	L	L
Market	H	H
Adhocracy	Very H	H

The above (Table 1) provides a comparison between AI and MI only; and not compared with cost leadership and differentiation strategy. As PD is very low (on an average) the national culture will percolate into AI/MI; and will influence compensation expected by its employees. It is given below.

Now we relate compensation and type of innovation in Table 2 and Table 3.

Table 2: Relating Culture, Architectural Innovation to Compensation

	Architectural Innovation	Compensation
Power Distance	H in enforcing patent and in knowledge leakage to its competitors; and L elsewhere	No social class benefits
Uncertainty	Very high	High Incentive to take risks (AI is the riskiest business model).
Individuality / collectiveness	Collectivism: H	High Group Incentive schemes
Short Term / Long Term	Highly LT	LT oriented
Masculine / Feminism	Masculine: H	**
Bureaucracy	Masculine: H	**

Professional	H	**
Person Support	L	**
Market	H	**
Adhocracy	Very H	High Incentives for Trying out several possibilities (even if nothings nothing comes out) as it helps in cutting out the feasible region.

Table 3: Relating Culture, Modular Innovation to Compensation

	Modular	Compensation
Power Distance	H due to explicit K in may modular products; and L otherwise	No social class benefits
Uncertainty	Low	Low Incentive to take risks (AI is the riskiest business model).
Individuality / collectiveness	Collectivism: L	Low Group Incentive schemes; as it practices decentralization
Short Term / Long Term	LT	Not LT oriented:
Masculine / Feminism	Masculine:H	**
Bureaucracy	L (as in AI K management is very important & needs bureaucratic procedures to put tacit K into explicit K)	**
Professional	H	**
Person Support	L	**
Market	H	**
Adhocracy	H	Low Incentives for Trying out several possibilities (only bottleneck technology is on the floor; & rest all technologies are licensed).

We note that National Culture Percolates into the organization for AI/MI (as PD is low in general) and will have its own effect on compensation.

It has been noted in literature that it is difficult to keep exploration and exploitation under the same roof (USR). It has been noted by many that innovative conglomerates. are keeping exploration and exploitation under the same roof (USR): these are small base of resources (for small firm), short product life cycles etc. Alternatives are suggested to try and make a compromise by (1) Outsourcing (2) Separate Exploitation and Exploration and align them (3) cycle back and forth between exploration and exploitation and (4) continuous and incremental reconfiguration. We note that exploration and exploitative processes are happening in both modular and architectural innovation. Now we argue as given below.

(H90): Option (1) as above to be followed predominantly in modular innovations; and Option (4) as above to be used predominantly in architectural innovations.

3. Conclusion

In this theoretical paper we give a rich framework that relates modular and architectural innovation to various organizational variables (strategy, personality of knowledge workers, culture, VT/ESM). These are likely to be useful to top management of AI/MI who can set controllable organizational variables at required levels. These hypotheses (presented in this paper) are available in scattered form in Sharma (2019, 2020 and 2021). Here these are presented as a unified whole. We are undertaking a empirical investigation to verify above framework; and we will get back with results.

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